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Perspective 1
MG Russell J. Czerw

Chemical Defense Against Blood-Feeding Arthropods by Disruption of Biting Behavior 4
COL Mustapha Debboun, MS, USA; Jerome A. Klun, PhD

The Deployed Warfighter Protection Research Program: Finding New Methods to Vanquish Old Foes 9
CAPT Stanton E. Cope, MSC, USN; COL (Ret) Daniel A. Strickman, MS, USA; Graham B. White, PhD

Support of Far-Forward Disease Surveillance Operations with Deployable, Real-Time Vector-Borne Disease Agent Analytic Capability 21
Col James A. Swaby, BSC, USAF; James C. McAvin

Level III Preventive Medicine in a Counterinsurgency Environment 25
MAJ Derek J. Licina, MS, USA

Preparing the Force for the Chemical, Biological, Radiological, and High Yield Explosives Battlefield; Today and Tomorrow 36
LTC Gary Matcek, MS, USA; Scott Crail, MS; SFC Courtney Moore, USA; James Bernardo

The Army Preventive Medicine Specialist in the Medical Education and Training Campus Era 40
LTC Dennis B. Kilian, MS, USA; SFC Roye L. Patton, USA; HMCS William Adams, USN

Malaria Risk Assessment for the Republic of Korea Based on Models of Mosquito Distribution 46
Desmond H. Foley, PhD; et al

The US Air Force Aerial Spray Unit: A History of Large Area Disease Vector Control Operations, WWII Through Katrina 54
Maj Mark Breidenbaugh, BSC, USAFR; Maj Karl Haagsma, BSC, USAFR

Evolution of the Army Hearing Program 62
MAJ Scott McIlwain, MS, USA; et al

Perspectives of Malaria and Japanese Encephalitis in the Republic of Korea 67
LTC William J. Sames, MS, USA; Heung-Chul Kim, PhD; COL (Ret) Terry A. Klein, MS, USA

Health Implications of Occupational Environmental Health Sampling 74
Coleen Weese, MD, MPH

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Perspective

Major General Russell J. Czerw

The Department of Defense defines the term *force multiplier* as

> A capability that, when added to and employed by a combat force, significantly increases the combat potential of that force and thus enhances the probability of successful mission accomplishment.[1]

Military planners, strategists, and analysts generally use the term as related to factors such as technology, intelligence, training, tactics, terrain, etc. However, over the last century, the science and practice of preventive medicine in the military has itself become an increasingly significant force multiplier. Nonetheless, the contributions of preventive medicine are often not recognized as such following successful military campaigns. On the other hand, the absence of effective measures are immediately apparent, for all the wrong reasons. In early 1943, following the extremely difficult and costly opening campaigns against the Japanese in Paupau New Guinea, General MacArthur was told that 72% of the combined Allied force was sick, 60% with malaria. His brief response clearly captures the indisputable value of preventive medicine as a force multiplier:

> Doctor, this will be a long war if for every division I have facing the enemy, I must count on a second division in hospital with malaria and a third division convalescing from this debilitating disease.[2]

General MacArthur's remarks were indicative of the increasing awareness among top level commanders of preventive medicine's vital role in combat operations. Over time, that evolving realization has resulted in top-down emphasis, policies, and regulations to institutionalize preventive medicine as an integral part of the planning and execution of training and operational deployments.[3]

Fortunately, increasing awareness of preventive medicine's role in the improvement of human health has not been limited to the military. Governments at all levels have established policies and regulatory frameworks, committed resources, and conducted public awareness programs targeted at the improvement of the overall health of their populations.

As with most areas of medical science, the practice of preventive medicine transcends the military-civilian

boundary. In this regard, military medicine is very fortunate to have been both beneficiary of and contributor to its progress over the years. This issue of the *AMEDD Journal* focuses on the science and practice of preventive medicine from a military perspective, while featuring articles that reflect the mutual benefits to both sides from the overlap of knowledge, practices, and purpose.

COL Mustapha Debboun and Dr Jerome Klun open this issue with a stimulating article exploring the background and current science of synthetic organic chemical arthropod repellents. As related in their article, the world's first truly effective insect repellent was developed in a collaborative effort of the US Army and the Department of Agriculture, which began during World War II. They detail the chemistry of what are currently the 3 most effective compounds and the experiments that explore the mechanism of their repellency. This research is a prime example of the type of partnerships between military and civilian that are so effective in the science of preventive medicine.

The importance of such collaboration to the military is demonstrated in the next article. CAPT Stanton Cope, USN, and his coauthors describe the Deployed Warfighter Protection research program (DWFP), an innovative, forward-thinking DoD effort to tap into nonmilitary talent and resources in the search for new ways of protecting our deployed personnel from

vector-borne diseases. The DWFP provides funding to both government and nongovernment research projects which are exploring new and better ways of troop protection. Although the DWFP is a recent initiative, the results have been an ever-increasing level of knowledge in the sciences involved, with attendant improved sophistication in techniques and procedures, as well as a number of products created specifically for dealing with the insect threat.

Knowledge of the specific disease threats in a deployment area is critical in determining the type of preventive medicine measures which are required for force protection. Current data may or may not be available, or accurate, and obtaining such information has always been a time-consuming, multifaceted undertaking. Col James Swaby, USAF, and James McAvin have been involved in the development of a system that will allow forward deployed units to assess the local threat of vector-borne diseases in real-time, without dependence on far-away laboratories. Their article details the Vector Surveillance Analytic System, a vitally important advancement in our arsenal of weapons to protect the health of our Warriors.

Since the end of combat in Korea in 1953, the character of military conflict has evolved from the classic model of conventional warfare between armies into operations against shadowy, low-tech, loosely organized insurgencies. MAJ Derek Licina has contributed a profound, well-researched article that spotlights how counterinsurgency operations are rarely won with overwhelming firepower alone, but with other operations targeting the conditions which provide the base of support for those insurgents. Preventive medicine can and should be a major component of such operations. This important article is developed using the history of such conflicts combined with extensive experience with current counter-insurgency operations in the middle east. MAJ Licina proposes thoughtful changes in doctrine, organization, and training of Army preventive medicine designed to significantly improve its capability to directly contribute to long-term counterinsurgency operations. The principles and science of preventive medicine may indeed be the “secret weapon” that will effect a favorable shift in both the physical and ideological environments of modern military conflict.

An ironic reality of the shift in the character of military operations to the fluid, ill-defined, counterinsurgency environment is the increased potential for the use of unconventional weapons, at almost any time or place. Insurgents have no political, moral, or ethical limitations to their actions, and are not concerned about repercussions. Their lack of sophistication increases the potential danger that chemical, biological, radiological, or high yield explosives (CBRNE) could be used in almost any scenario, including accidentally during transport or storage. LTC Gary Matcek and his team from the CBRNE Sciences Branch have contributed an article describing both the training of medical personnel to cope with the evolving threats, and the development of new tools and protocols to enhance their capabilities. The danger represented by CBRNE weapons is not limited to the battlefield or military installation. The importance of this component of preventive health science cannot be overemphasized.

One of the many changes stemming from the latest round of the Base Closure and Realignment Committee activity is the consolidation of a significant portion of Army, Navy, and Air Force medical enlisted training at Fort Sam Houston. The Medical Education and Training Campus is a result of that initiative. LTC Dennis Kilian and his coauthors describe in detail the meticulous collaborative process that resulted in the plan for consolidated training of enlisted preventive medicine personnel. Their article provides insight into the plans for both the academic syllabus changes and the personnel and physical infrastructure requirements necessary to make the concept a reality.

Even after years of intensive research and countermeasures, malaria remains one of the most persistent, and deadly, vector-borne health threats in the world today. Assessment of the risk of malaria in a given geographic region is the first step in planning to address its threat. Since malaria is transmitted solely by several species of the *Anopheles* mosquito, identification of the actual and potential distribution of those species in a geographic area could be a valuable tool in the development of the risk assessment. Dr Desmond Foley and his coauthors present a new approach they developed to model the distribution of malaria vectors, using the US military installations on the Korean peninsula as the areas of interest. Their detailed and clearly presented article demonstrates the immeasurable value of the symbiotic relationship of military and civilian resources and talent in the war against vector-borne disease. The increase in the number and capabilities of data-gathering sources,

combined with increasingly sophisticated analysis and modeling techniques are powerful weapons in the hands of dedicated professionals such as Dr Foley and his team. Innovative work such as this will continue to evolve, to the benefit of everyone, everywhere.

In 1918, an airplane was used to distribute insecticide for the first time.[4] Since then, aerial application of pesticides has been an invaluable tool for both agriculture and preventive medicine. USAFR Maj Mark Breidenbaugh and Maj Karl Haagsma have written an excellent article about one of today's US military aerial spray capabilities, the USAF Aerial Spray Unit (AFASU). Their article traces the long history of this versatile unit, and describes its multiple roles in responding to both military and civilian requirements throughout the United States and overseas. The article focuses on large area insect problems, especially mosquitoes, which become very serious in the aftermath of hurricanes. The AFASU's response to Hurricane Katrina in Louisiana is detailed as an illustration of the extensive planning and close cooperation between the military and civilian preventive medicine authorities that is required to ensure a timely and effective response. The article provides an informative overview of this unique capability, and the high level of professionalism of those who perform the vitally important missions.

Hearing is something that most of us take for granted, yet it is one of the most important, and most vulnerable, of our senses in a survival situation, including combat. Not surprisingly, some loss of hearing is one of the most common conditions among military veterans. Extremely loud noise is an unavoidable part of military operations, but hearing loss in not inevitable. In their informative article, MAJ Scott McIlwain and his coauthors provide an overview of the conditions that contribute to hearing loss, and statistics that demonstrate the surprising extent of that loss among military members today. They detail the various research, techniques, and equipment used to address this hazard, which has resulted in the Army Hearing Program, the current structure designed to provide effective loss prevention services at all locations, including forward deployed areas. This article contains important information which should be of interest to everyone, military or civilian.

Despite all of our efforts since the Korean War, malaria and Japanese encephalitis remain valid threats in Korea. LTC William Sames and his coauthors have contributed an important article describing the situation faced by our Warriors and their families, as well as the Korean population as a whole, and the ongoing efforts to control the threat posed by the two diseases. The article is packed with information about the cycles of infection and transmission for each disease, the hosts that harbor the pathogens, and the cooperative relationships between the US military preventive medicine specialists and the various Korean agencies in actions to address these threats. As clearly illustrated throughout the articles in this issue, there are no boundaries to preventive medicine's importance to health, whether civilian, military, or national.

At first look, evaluation of the health of Soldiers returning from deployment would seem straightforward—a physical examination focused on injuries and whatever illnesses the Soldier may have incurred during the deployment period. However, the extent of follow-on illnesses that are a result of deployments has been recognized only relatively recently. Dr Colleen Weese's article is an eye-opening look at the complexities involved in quantifying the problem of environmental hazards, and the measures implemented to address those hazards for our deploying Warriors. The results include a program that collects and catalogues worldwide environmental data for area assessments, a system that maintains the exposure history of military personnel throughout their lifetime, and formalized requirements for the sampling and evaluation of air, water, and soil from the deployment area. Most importantly, significant exposures must now be documented in the individual medical record. Dr Weese's article demonstrates the responsiveness of the military medical system, and the extent of our efforts to protect the health of our dedicated Warriors, whether immediate or long-term.

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Chemical Defense Against Blood-Feeding Arthropods by Disruption of Biting Behavior

COL Mustapha Debboun, MS, USA
Jerome A. Klun, PhD

In military operations, vector-borne diseases and associated discomfort caused by biting arthropods can be largely prevented with proper use of personal protective measures, particularly arthropod repellents. When appropriately applied, such repellents are the first line of defense against a wide range of arthropod-borne pathogens and will preserve the fighting strength of the troops. The bites of arthropods transmit many of the disease-causing agents that cause our military the most trouble. These diseases can take Soldiers out of the action, make them miserably sick, or even kill them. In addition, the diseases and the arthropods that transmit them are as much of a threat during routine field training exercises or humanitarian/disaster assistance operations as during actual combat.

Arthropod repellents provide military commanders with a quick and inexpensive measure to protect the force in any military situation, no matter how quickly the unit is involved in action. They can be applied effectively to prevent any arthropod-borne disease, whether or not surveillance has identified the pathogen. Arthropod repellents are often the only means of protection against arthropod-borne diseases in combat environments when vector control measures are not possible, or when the speed of military developments prevents the use of chemoprophylaxis or vaccines. In addition, commanders will be able to minimize incidence of any vector-borne disease, providing a tactical advantage against an unprotected enemy force which does not have the benefit of an effective, long-lasting arthropod repellent.

The Department of Defense (DoD) Insect Repellent System is available for use by all military personnel to prevent arthropod-borne pathogens that cause diseases such as malaria, leishmaniasis, trypanosomiasis, scrub typhus, West Nile fever, and Lyme disease. As shown in Figure 1, the repellent system consists of 3 components: permethrin on uniforms (and bed nets), deet on exposed skin, and proper wear of the uniform. When used properly, this system will prevent disease, pain, and the annoyance caused by bites of insects such as mosquitoes, sand flies, ticks, and chiggers. The repellent system is critical to the Army Medical Regiment's motto to "Conserve the Fighting Strength," and is a mission essential task contained in *Soldier Training Publication 21-1*.[1] Further, DoD policy mandates that every Soldier, Sailor, Airman, and Marine must strictly follow the guidelines and methods of the repellent system. Details are found in the *Armed Forces Pest Management Board Technical Guide 36*[2] and in the US Army Center for Health Promotion and Preventive Medicine fact sheet on the DoD Insect Repellent System[3] and at the US Army Medical Department Center and School deployment training portal website.[4]

DoD operates the Walter Reed Army Institute of Research and 5 other US overseas laboratories: Armed Forces Research Institute of Medical Sciences,

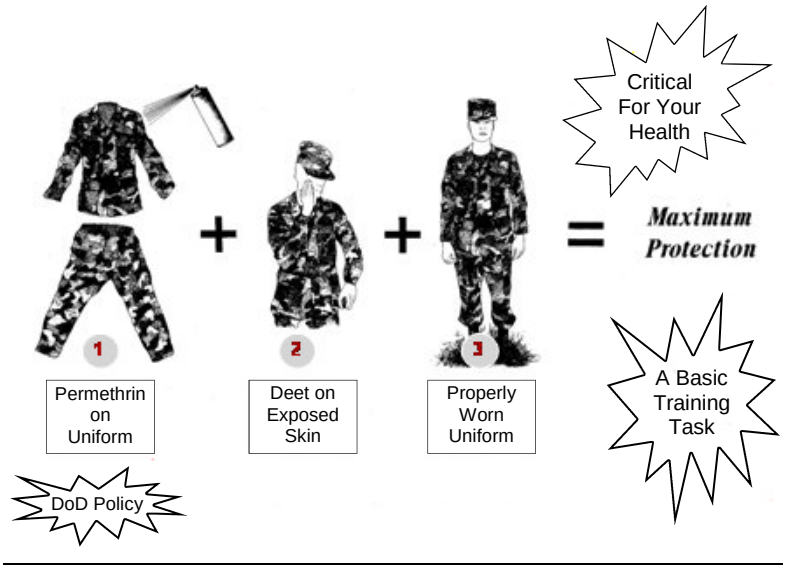

Figure 1. The DoD Insect Repellent System

Bangkok, Thailand; US Army Medical Research Unit-Kenya, Nairobi; Naval Medical Research Center Detachment, Lima, Peru; Naval Medical Research Unit-2, Jakarta, Indonesia; and the Naval Medical Research Unit 3, Cairo, Egypt. These resources, combined with collaborations with the US Department of Agriculture, Agricultural Research Services and the Australian Army Malaria Institute, place the US military in an outstanding position to test and evaluate repellents in the laboratory and in the field against vectors of many disease-causing pathogens.

All haematophagous arthropod pests such as female mosquitoes, sand flies, mites, black flies, and ticks require a blood meal to produce eggs and complete their life cycles. Males do not blood feed. Thus, thankfully, only half of the population of such arthropod species are biters and blood-feeders. The biting activity of females is complex and they may preferably feed only on specific hosts such as reptiles or birds. In some species, the females may have multiple hosts which often include humans. It is these arthropod species of blood-feeders that are simply annoying, or represent vectors of dangerous pathogenic diseases that can injure or kill. The diseases vectored are many and include malaria, leishmaniasis, dengue, yellow fever, West Nile fever, Lyme borreliosis, and spotted fevers. Throughout history, humans have struggled against the blood-feeding arthropods, and the struggle continues today in full force.

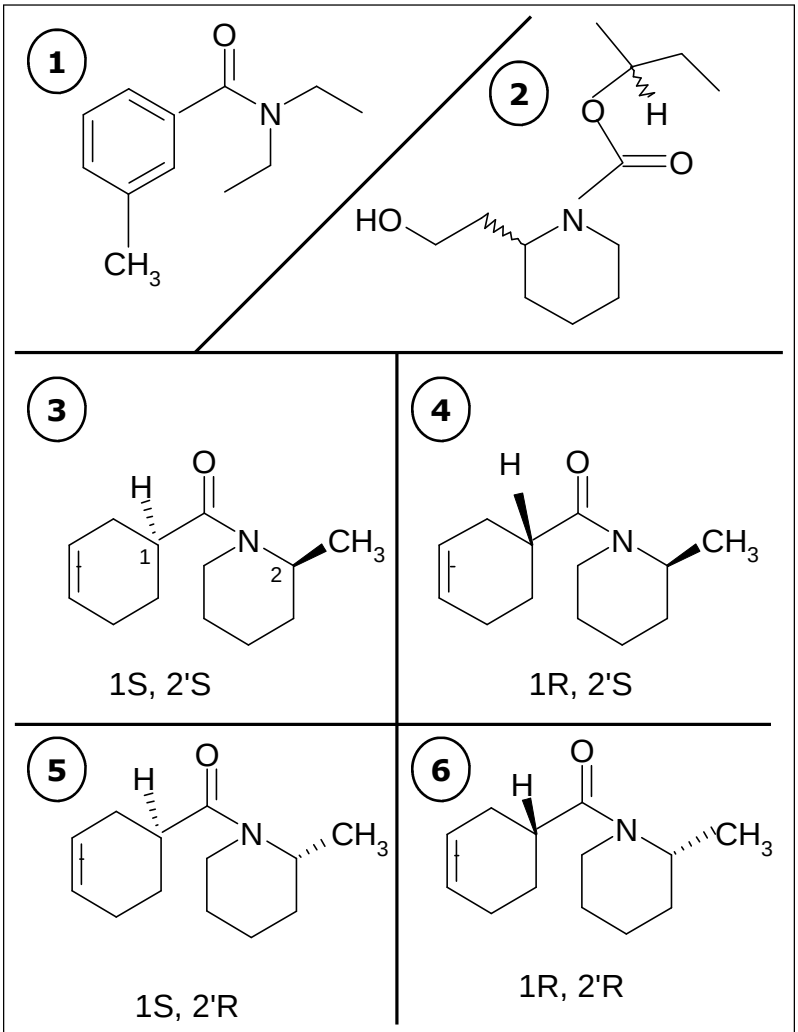

Figure 2. Chemical structure of Deet, KBR3023, and the diastereo-isomers of AI3-37220.

Synthetic organic chemicals have proven effective in interfering with arthropod blood-feeding behavior, and can offer personal protection against the bites of nuisance pests and disease vectors by topical application to skin or clothing.[5,6] Several notably effective synthetic repellent compounds, the structures of which are shown in Figure 2, are: *N*,*N*-diethyl-3-methylbenzamide (deet) (structure 1), 2-(2-hydroxyethyl)-1-piperidinecarboxylic acid 1-methylpropylester (variously known as KBR3023, Bayrepel, Picaridin or Icaridin) (structure 2), and (1S, 2'S)-methylpiperidinyl-3-cyclohexene-1-carboxamide (SS220) (structure 3). Each of these repellent compounds has an interesting developmental history, and each is known to interfere with arthropod blood-feeding behavior.

Deet was developed in 1954 as an outgrowth of an intensive systematic chemical search for synthetic personal-protection chemicals that began during World War II with a collaborative effort involving the US Department of the Army and the Department of Agriculture (USDA), Bureau of Entomology and Plant Quarantine.[7,8] In the years following its development, deet became the standard personal protection repellent product of choice for use by the general public and military organizations worldwide. The use of deet was so universal that it became an anthropogenic organic chemical pollutant in many bodies of surface waters ranging from the Tama River in Japan and the Rhine River in Germany, to the waters of the North Sea.[9]

In 1996, the discovery of KBR 3023 was announced,[10] and the racemic compound was subsequently commercialized worldwide by Bayer. This compound contains 2 asymmetric centers as indicated in Figure 2, structure 2, and, therefore, the racemic compound is composed of 4 diastereoisomers. Preliminary work with the yellow fever mosquito, *Aedes aegypti*, indicated that the 1R, 2'S diastereoisomer of KBR 3023 (RS-KBR 3023) was the most effective in deterring mosquito biting.[11] The KBR 3023 efficacy might be improved by using the most biologically active form of its 4 stereoisomers. Independent field and laboratory bioassays with the racemic KBR 3023 generally show that it effectively reduced bites of mosquitoes, sand flies, noseeums, and ticks, and effectiveness of the compound was often equivalent to deet.[12-18] In human volunteer laboratory bioassays with *Ae. aegypti*, we found that deet and SS220 were equally effective and more effective, respectively, than KBR 3023 in suppressing its biting.[19] The 3 repellent compounds were equally effective against *Anopheles stephensi*. Internet searches indicate that Lanxess and S.C. Johnson, respectively, are actively involved in marketing this compound.*

The racemic 2-methylpiperidinyl-3-cyclohexene-1-carboxamide was first identified as an insect repellent by McGovern et al,[20] and the USDA assigned the compound the code number AI3-37220. Like KBR 3023, AI3-37220 contained 2 asymmetric centers, and achiral synthesis yielded a racemic mixture of 1S, 2'S, 1R, 2'S, 1S, 2'R and 1R, 2'R diastereoisomers (Figure 2, structures 3, 4, 5, and 6). The racemic mixture proved to be effective against the biting behavior of a wide variety of blood-feeding arthropods.[21-29]

A study of the stereoisomers of AI-37220 showed that the 1S, 2'S stereoisomer (SS220) was the most effective isomer of the four in reducing bites by *Ae. aegypti*,[30] and it is surmised that enhanced repellent effects can be realized through specific formulation of this most active stereoisomer. Toxicological tests indicate that SS220 is biologically pacific and amenable to dermal application to defend humans against many blood-feeding arthropods.

Deet, KBR 3023, and SS220 are among the most effective synthetic repellent compounds for protection against nuisance and blood-feeding arthropods that vector human diseases. Despite the widespread knowledge of the protective qualities of these repellent compounds,[17,19,31] there was, until recently, little information available on how the compounds mechanistically affect whole organism behavior and thereby suppresses the biting. A series of behavioral tests[32] with *Ae. aegypti*, *An. stephensi* mosquitoes and the sand fly, *Phlebotomus papatasi* in the presence of deet, SS220, and KBR 3023 topically applied to the skin of human volunteers showed that the insects were deterred from feeding on and repelled from surfaces emanating the compounds. When offered a 12 cm^2 or 24 cm^2 area of skin, one half treated with compound and one half untreated, the insects fed almost exclusively on untreated skin. The sand flies and mosquitoes did not at any time physically contact chemically-treated surfaces. When treated and untreated skin areas were covered with cloth, insects landed and bit only through cloth covering untreated skin. These observations provided evidence that the chemicals deterred feeding and repelled insects from treated surfaces primarily as a result of olfactory sensing. When cloth, one half untreated and the other half treated with chemical, was placed over untreated skin, insects only touched and specifically bit through the untreated cloth. This showed that the activity of the chemicals does not involve a chemical ⇆ skin interaction. In the presence of any of the 3 repellent compounds, no matter how presented to the insects, overall population biting activity was reduced by about one-half relative to the controls. The research indicates that the protection afforded by deet, SS220, and KBR 3023 against the insect feeding upon humans is mechanistically a combined consequence of feeding deterrent and repellent effects of the compounds.

The behavioral studies clearly showed that all 3 compounds were perceived by olfactory sensing, and it was curious that these man-made and structurally different compounds profoundly influenced the blood-feeding behavior of *Ae. aegypti*, *An. stephensi*, and *P. papatasi* in similar ways. Natarajan et al[11] conducted computer-assisted stereochemical structure-activity relationship and molecular overlay studies of SS220, KBR 3023, and deet to show that forms of compounds possessing the highest levels of repellent and feeding deterrent activity each have similar three-dimensional structural motifs. This suggests that the biomacromolecule(s) responsible for the olfactory

*Websites: http://www.bayrepel.com/bre/en/index.php
http://www.autan.com/nqcontent.cfm?a_id=1

recognition of the compounds in the insects is (are) specifically sensitive to the active space-matching qualities of SS220, RS-KBR 3023, and deet. The development of new behaviorally-active chemical tools for protection of humans against blood-feeding disease vectors will ultimately depend upon the extent to which the fundamental nature of this process is understood.

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The Deployed Warfighter Protection Research Program: Finding New Methods to Vanquish Old Foes

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INTRODUCTION

The Deployed Warfighter Protection research program (DWFP) is an initiative to develop and validate novel methods to protect United States military deployed abroad from threats posed by disease-carrying insects.[1] Vector-borne diseases such as malaria, dengue, leishmaniasis, and chikungunya are among the most important health risks facing deployed troops. There are no vaccines for many diseases transmitted by biting insects, so methods in insect management and control, as well as personal protection, are the primary tools available to protect troops.[2-5]

During and following World War II, scientists from the US Department of Agriculture (USDA) were regularly funded by the Department of Defense (DoD) to develop new methods and materials for controlling biting insects, particularly those that transmit diseases to humans. This highly successful collaboration produced tools that are still part of our insect-control arsenal today. Examples include:

- Deet (N,N-diethyl-3-methyl-benzamide), the primary ingredient in the majority of insect repellents available today.
- Ultra low volume application of insecticides, a methodology that distributes a limited amount of chemical per acre by optimizing the dispersion and concentration of size-limited droplets, now the standard method used by spray trucks deployed to protect neighborhoods against mosquitoes.
- Permethrin-impregnated fabrics for personal protection against the bites of ticks, mosquitoes, and other blood-feeding flying insects. Permethrin is a synthetic pyrethroid insect repellent that is used to treat uniforms, bed nets, tentage, and other fabrics.

*Detailed information on the DWFP can be found at http://www.afpmb.org/dwfpresearch.htm.

On a global basis, many diseases transmitted by insects are increasing and spreading (eg, chikungunya, dengue, West Nile fever) or remain widespread and prevalent (eg, malaria, leishmaniases, trypanosomiases) despite variable vector control efforts. This situation is demonstrated in Table 1. Also, increasing numbers of species of medically important insects are developing resistance to insecticides commonly used today. For strategic reasons, therefore, there is a critical need in the DoD for the types of products USDA is uniquely able to provide. The DWFP is designed to not only encourage the rapid development of such products, but also to improve the capability of USDA to provide long-term, innovative support to military preventive medicine. In short, it is the intent of the DoD, through the DWFP, to provide funding to the USDA Agricultural Research Service (ARS) to reinvigorate this mutually beneficial working relationship between DoD and USDA, particularly as it pertains to DWFP, as defined in 2 written agreements.[7,8]

ADMINISTRATION AND AREAS OF EMPHASIS OF THE PROGRAM

The DWFP is administered by the Research Liaison Officer of the Armed Forces Pest Management Board. The program, which was started in Fiscal Year 04, is funded at $5 million per year. It consists of a noncompetitive funding process for USDA ARS-based research, and a competitive grants process open to non-USDA ARS scientists. Up to $3 million per year is given to USDA ARS, specifically to National Program 104, dealing with Veterinary, Urban, and Medical Entomology. The funds are then distributed to various laboratories within the USDA system as described below.

Up to $1.4 million is awarded each year in new competitive grants. The amount available for new

Table 1. Major Global Vector-borne Diseases[6]

Vectors	Diseases	Incidence, Prevalence
Mosquitoes	Malaria	Warm regions—deaths in excess of one million per year
	Lymphatic filariasis	Warm regions—infections in excess of 200 million
	Arboviruses (chikungunya, dengue, Japanese encephalitis, Rift Valley fever, West Nile virus, yellow fever, etc)	Spreading—epidemics increasing
Flies and roaches	Dysentery	Global and repetitive
Sand flies	Leishmaniases	Focal—approximately 6 million infections a year
Fleas	Plague	Widespread—occasional outbreaks
Blackflies	Onchocerciasis (River Blindness)	Africa and Americas: focal—less than 10 million cases
Tsetse	African trypanosomiases (Sleeping Sickness)	Africa: focal—less than 5 million cases
Reduviid bugs	Chagas disease	Americas: 24 million cases across 15 countries
Ticks and mites	Borrelioses, ehrlichias etc	Widespread
Snails	Schistosomiasis	Warm regions—Approximately 200 million cases

starts each year depends on how many projects are carried over from previous years. Grants are awarded for up to $250,000 per year, for up to 3 years. The call for preproposals generally goes out around September. These are then reviewed by a DWFP Technical Committee, consisting of 8 to 10 members, civilian and military, representing the Army, Navy, and Air Force. Based on preproposal reviews, investigators may be asked to submit a full proposal. In November, the DWFP Committee convenes for a 2-day review of the USDA research and to determine which new competitive grants will be awarded. Final competitive award winners are usually notified in December.

The DWFP research portfolio is concentrated in 3 specific areas: novel insecticide chemistries/ formulations, application technology, and personal protective systems. The first area includes discovery of new active ingredients, tests of existing insecticides on pests and vectors of public health importance, especially mosquitoes and sand flies, and reformulation of existing insecticides to improve efficacy or delivery.

INVOLVEMENT OF THE US DEPARTMENT OF AGRICULTURE

The USDA ARS has been a partner in DWFP since 2004, but cooperation between the nation's agricultural research and the military goes back many decades. World War II was a unique moment in this relationship. American forces were faced with the usual disease challenges of warfare, but, for the first time, scientific understanding and industrial capacity combined to offer hope of preventing those diseases caused by vector-borne pathogens. The USDA Bureau of Entomology and Plant Quarantine laboratory in Orlando[9] targeted the flea vectors of plague, the louse vectors of typhus, the chigger vectors of scrub typhus, mosquitoes including vectors of malaria and yellow fever,[10] as well as bedbugs, cockroaches, flies, and ticks.[11] In just a few years, the laboratory refined the uses of DDT* as a control agent for public health pests and of repellent chemicals (ethyl hexanediol, dimethyl phthalate, dimethyl carbate, indalone, and benzyl benzoate) as topical and clothing repellents. Workers at the Beltsville Center invented the insecticidal

*1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane or Dichloro-diphenyl-trichloroethane

aerosol bomb[12] (precursor of all spray cans) for military use during WWII, and collaborated with the Orlando Lab to invent the repellent deet[13] in 1947.

The USDA continued to collaborate with the military through the 1970s and 1980s, most notably working out the means for permethrin treatment of military uniforms.[14-16] Concentration on military problems slowed, eventually reduced to the development of repellent active ingredients and improved trapping systems. The DWFP effort brought greater focus in 3 ways. First, it provided significant funds ($3 million per year) to the USDA ARS for research. Second, it defined the subject areas of most interest to the military, namely new toxicants for public health pests, new application equipment for pesticides, and new personal protection system. Finally, the DWFP established mechanisms of communication between the military and the USDA ARS that have kept both sides engaged in the conversation on the direction of research required to produce products for the protection of military personnel from arthropods that transmit pathogens.

During the last 3 years we have conceived and executed the concept of a "virtual laboratory" that takes advantage of the core strengths of the USDA ARS at each of the laboratories to establish a smooth flow for development of new vector control products. Chemical discovery proceeds from several strategies that are, for the most part, based on basic science rather than bulk screening. Promising candidates emerge from bioassays, leading to more comprehensive evaluation against target insects. Once we have what we think is a useful chemical, we consider how best to use it against target insects in an integrated pest and disease management program. With those goals in mind, we have in the past approached individual private companies in order to form a partnership for further development. In that case, it is up to the company to formulate the active ingredient. Recently, we have been performing research on formulation, reasoning that a preparation closer to product status may be more attractive for industrial development. We are also working on regulatory issues by funding a position on public health pesticides with IR-4*, the USDA-funded entity that supports registration of pesticides for use on specialty crops.[17]

Some USDA ARS laboratories and investigators have had only a temporary involvement with DWFP, depending mainly on whether the core agricultural mission of their unit effectively synergized the military mission of the funds. Currently, there are 5 laboratories that receive DWFP funding. The following sections discuss some of the work underway in those laboratories.

Invasive Insect Biocontrol and Behavior Laboratory

The Invasive Insect Biocontrol and Behavior Laboratory in Beltsville, Maryland, is the laboratory that first patented deet[13] the dominant active ingredient in American insect repellents. It continues to be well-equipped to perform any level of synthetic and analytical chemistry, an obvious advantage for a laboratory attempting to discover new toxicants and repellents. Chauhan and colleagues[18] have been involved in the discovery of promising new repellent active ingredients, mosquito larvicides, and exciting new insecticidal chemistries. He takes advantage of a small *Aedes aegypti* colony on site and performs simple, screening bioassays to guide his work. Another research team is at the cutting edge of research on how mosquitoes detect hosts.[19] Using molecular biology and electrophysiology, they will develop tools that dissect biting behavior into its component, physiological parts. Combined with the synthetic chemistry of the laboratory, this work will provide very precise pathways for discovering entirely new behavior-altering chemicals. Potential products could be chemicals that selectively repel infected mosquitoes, chemicals that induce mosquitoes to bite nonhuman hosts, and powerful attractants that could be combined with toxicants.

Mosquito and Fly Research Unit

Scientists at the Mosquito and Fly Research Unit (MFRU) in Gainesville, Florida, are experts on many aspects of the biology and control of mosquitoes and flies. Their work includes the following:

*Interregional Research Project No 4 (IR-4), the Minor Crop Pest Management Program, is the principal public effort supporting the registration of crop protection products and biological pest control agents for approximately $40 billion minor crop industry. Source: USDA Cooperative State Research, Education, and Extension Service, http://www.csrees.usda.gov/nea/pest/in_focus/ipm_if_minor.html

- Toxicant discovery by Pridgeon et al[20] includes tests of registered toxicants that have not yet been applied for public health pests. They also work with industry to explore the effectiveness of new compounds that have not been used as insecticides. Promising chemicals have also been extracted from native plants.
- Pridgeon and associates[21] have invented an entirely new class of "molecular pesticides" that promise to combine great safety, flexibility, and specificity.[22,23]
- Bernier and colleagues have extended fundamental work to the production of inhibitors for mosquitoes (patent pending) and powerful attractants for flies[24] and mosquitoes.[25] Collaborators at the University of Florida are using computational chemistry (QSAR/QSPR*) to reanalyze pesticide bioassay data generated over 50 years at the Orlando and Gainesville laboratories, resulting in synthesis of repellents with 3-fold longer repellency than deet.[26]
- Researchers Cooperband and Allen[27] have also explored the effects of sublethal dosages of pesticides on mosquito behavior using quantitative interpretation of videos, extending our knowledge of how best to apply residual insecticides.
- Research is underway on fly control, including trapping and toxicants, at field sites in the United States and middle eastern locations.
- The Center for Medical, Agricultural, and Veterinary Entomology, which includes the MFRU, has been very active in developing field tests sites, including Thailand; Kenya; Camp Blanding, Florida; and the Coachella Valley, California. The MFRU works closely with the Navy Entomology Center of Excellence at the US Naval Air Station, Jacksonville, Florida, especially for field testing and evaluation of application equipment.

Biological Control of Pests Research Unit

At the Biological Control of Pests Research Unit (BCPRU) in Stoneville, Mississippi, Lyn and Streett[28] collaborate with scientists at the MFRU and industry to develop formulations of public health pesticides. Also, the BCPRU has facilities for pilot production of biopesticides.

*Quantitative structure-activity relationship/quantitative structure-property relationship

Natural Products Utilization Research Unit

The Natural Products Utilization Research Unit in Oxford, Mississippi, has a history of working in partnership with the University of Mississippi School of Pharmacy on the discovery of natural sources of bioactive compounds. The unit goes beyond simple extracts to complex analysis of families of chemicals and optimization through synthesis of series of compounds. Thanks to DWFP funding, USDA was able to leverage the effort by transferring funds to the University of Mississippi for insecticide development. Cantrell and colleagues[29,30] have already been involved in discovery and patent of repellents and toxicants. The products of their research will be screened on site using a new and very simple bioassay developed by Becnel and Pridgeon[31] at the MFRU. Promising candidates will be evaluated in more detail by the MFRU.

Areawide Pest Management Research Unit

Hoffmann and associates[32,33] at the Areawide Pest Management Research Unit (APMRU) in College Station, Texas, have worked closely with the MFRU and the Navy Entomology Center of Excellence to systematically evaluate the droplet spectra of a wide range of application equipment. The data have already informed the military on the best equipment for its purposes. Also, Nachman's[34] completed work on neuropeptides of public health pests, including mosquitoes, ticks, and flies, has established an entirely new potential mechanism for insecticidal mode of action.

COMPETITIVE AWARD HIGHLIGHTS

Publicly posted on the federal government's website† announcing grant availability, DWFP requests for preproposals have yielded an average of 38 submissions annually, from academics, military entomologists, industry, and others around the world. More than one-third of these have been invited to prepare full proposals, from which 34 projects, shown in Table 2, have been selected for grant funding during the first 5 years of the program. The range of topics and the quality of many proposals have been impressive. Indeed, many of the intended products could find wider applications for public health and veterinary pest control. So far, the smallest grant value was $22,552 over 2 years, while some grants have

† http://www.grants.gov/

Table 2. Deployed Warfighter Protection Research Program Competitive Project Grants

Award Recipient	Purpose	Org*	Highlights
2004 (n=8)			
CDR Claborn (Dr Walker)	Sprayer diesel conversion	M	2 prototypes & NSN†
LTC Coleman	Sand Fly control--Iraq	M	Improved field operations
LCDR Hoffman	Mosquito control with UAV‡	M	Passed to USAF
Prof Phil Koehler	Filth & Biting Fly control	A	1 NSN† & 2 deployed citations
Dr Bob Peterson	Comparative risk analyses	A	Publications & public appreciation
Dr Steve Presley	Hollow fiber impregnated fabric	A	Novel technology
Dr Bill Reifenrath	Repellent synergy	D	Cancelled
Dr Ed Rowton	Sand Fly control--laboratory	M	Essential collaborations
2005 (n=7)			
Prof Chas Apperson	Dengue vector ovitrap	A	Duty under instruction student
Prof Lane Foil	Targeted sand fly control	A	WRAIR§ collaboration
LT Haagsma	Mosquito control with UAV‡	M	Passed to USDA ARS APMRU
Dr Que Lan	Novel mosquito insect growth regulator	A	Product licensed
Dr Mike Scharf	Low molecular weight insecticides	A	Industry support
LT Stancil (LCDR Florin)	Dengue vector larval control	M	EPA¶ registration in preparation
Prof Alon Warburg	Sand Fly control military camps	A	WRAIR§ collaboration
2006 (n=6)			
Bruce Dorendorf	Diesel backpack	D	NECE** collaboration
Bruce Dorendorf	Ultra low volume nozzle	D	NECE** collaboration
Dave Malone	New ultra low volume adulticide etofenprox	D	EPA¶ registration in progress
Dr Phil Kaufman	Novel compounds	A	Duty under instruction student
Dr Bob Peterson	Comparative risk analyses	A	Strategic appreciation
Dr Gaby Zollner	Novel vapor repellent	M	Delayed
2007 (n=3)			
Dr Ed Rowton	Sand Fly control—WRAIR§ laboratory	M	Essential collaborations
MAJ Richardson	Sand Fly insectary, USAMRU-K††	M	Pioneering service
Dr Dolan & Dr McAllister	Natural product pesticides	G	CDC-NCZVED‡‡ collaborations
2008 (n=10)			
Bruce Dorendorf	Ultra low volume backpack diesel system	D	
Prof Lane Foil	Sand Fly larval control	A	
MAJ Stephen Frances	Australia field repellent fabrics	M	
Philipp Kirsch	Adulticides targeting Sand Flies	D	
Prof Phil Koehler	Military protections vs Filth Flies	A	
Richard Poche	Host-target insecticides vs Sand Flies	D	
LT Richardson	Novel tools & strategies vs *Ae.aegypti*	M	
Prof Masoud Salyani	Spray methods vs Sand Flies	A	
Prof Alon Warburg	Phlebotomine control	A	
Dr Mike Willis	Formulate UW4015 larvicide	D	

*Type of organization:
A – Academia (n=14) D – Industry (n=8)
M – Military (n=11) G – Other government (n=1)
†National Stock Number
‡Unmanned aerial vehicle
§Walter Reed Army Institute of Research
¶US Environmental Protection Agency
**Navy Entomology Center of Excellence
††US Army Medical Research Unit, Kenya
‡‡US Centers for Disease Control and Prevention–National Center for Zoonotic, Vector-Borne, and Enteric Diseases

exceeded $200,000 per year for 3 years. Awardees are encouraged to seek patents and find licensees for their products, several of which are already nearing commercialization.

For example, in 2005 a grant was awarded to ADAPCO (Sanford, Florida) to develop etofenprox[35] for use as mosquito ultra low volume (ULV) adulticide. This chemical, a nonester pyrethroid manufactured by the Mitsui Group in Japan and licensed to Central Life Sciences (Schaumburg, Illinois) for US registration for public health applications, is far less toxic to humans, animals, and birds than most other insecticides currently used for mosquito control.[36] It is expected to receive EPA approval for marketing this year.

Although the DWFP program prioritizes the discovery and development of agents for use against blood-feeding adult mosquitoes and biting flies that would afflict deployed military personnel, some research grants have been awarded for development of chemicals with new modes of action against mosquito developmental stages in water. At the University of Wisconsin, Madison, Lan and colleagues[37-41] had the idea to block sterol carrier proteins that are metabolically essential for the nutrition and growth of mosquito larvae. After screening tens of thousands of candidate compounds, they discovered several with the power to block mosquito sterols, effectively serving as growth inhibitors. The most appropriate compound has been licensed by a commercial company where it is being formulated for applied use. Both phases of the work have been supported by DWFP grants.

Figure 1. Yamaha RMax unmanned aerial vehicle fitted with ULV spray nozzles (top) and with twin hopper (bottom) for application of granular larvicide to control mosquitoes.

Among DWFP grants awarded to scientifically qualified military officers, the first was for adapting an unmanned aerial vehicle, shown in Figure 1, to carry application equipment for delivery of larvicidal granules or ULV adulticide. This project originated with the Disease Vector Ecology and Control Center (now the Navy Entomology Center of Excellence) at the Jacksonville Naval Air Station, where capabilities were demonstrated, then adopted by the USAF Aerial Spray Unit* at Youngstown, Ohio. To further develop this application technology with an unmanned aerial vehicle platform made in the United States, the project has been transferred to the Application Technology Laboratory of the USDA ARS at the APMRU. This relay of progressive research and development steps has been facilitated by DWFP funds and objectives to meet one of the strategic DoD goals of fielding unmanned vehicles.

Also by collaboration with the Navy Entomology Center of Excellence, a series of DWFP grants have enabled Dorendorf Advanced Technologies, Inc (Winnebago, Minnesota) to design and build new sprayers using military fuels instead of gasoline. The first backpack system, shown in Figure 2, operates almost silently with compressed air from cylinders charged by a diesel-fuelled compressor which also drives a truck-mounted ULV sprayer, the Terminator™. In addition to the strategic advantages of silent spraying, a unique ULV nozzle is being created for the backpack system. Altogether, this

*See related article on page 54.

purpose-built, diesel-fuelled spray equipment will allow troops to be deployed with battlefield-ready spray equipment for vector control.

Figure 2. The first backpack ULV sprayer system developed under DWFP grants operates almost silently with compressed air from cylinders.

From diverse proposals for better insect repellency of fabrics to protect military personnel, one DWFP grant was awarded to researchers at the Institute of Environmental and Human Health, Texas Tech University, Lubbock, Texas. That ingenious project developed a new type of permethrin-impregnated hollow fiber capable of being integrated with many textiles. This durable microcapillary can serve as a convenient carrier fiber for weaving the repellent and insecticidal powers of permethrin into any fabrics used for making clothes, curtains, tents, and other protective layers.*

Two DWFP projects have employed pyriproxyfen, the most powerful insect growth regulator (IGR), against dengue vector mosquitoes. In the Peruvian Amazon community at Iquitos, Stancil[42] (Naval Medical Research Center Detachment, Peru) received a grant to optimize strategies for preventing the breeding of *Aedes aegypti* mosquitoes in containers of water. The project ran for 3 years, and involved collaboration with Peruvian scientists and researchers from the University of California and Rothamsted Research, United Kingdom. In addition to simply stopping the breeding of mosquitoes in treated habitats, effective quantities of pyriproxyfen IGR are transferred from one container to another by mosquito females as they go from site to site laying their eggs, thus impacting more habitats than were treated directly. Mosquito population suppression across whole suburbs of the city has effectively prevented dengue transmission without the need to spray adulticides. Building on that achievement, researchers at the Armed Forces Research Institute of Medical Sciences, Bangkok,[43] in conjunction with local military personnel in Thailand, are now evaluating several devices treated with pyriproxyfen IGR for protecting military camps against *Aedes aegypti* and the arboviruses transmitted by this widespread domestic mosquito (see Table 1).

Figure 3. *Phlebotomus* sand fly (Photo courtesy of Ed Rowton, PhD)

The biggest emphasis of DWFP projects has been to find ways to combat *Phlebotomus* sand flies (Figure 3) which are problematic in many parts of the Middle East. These small hairy flies transmit *Leishmania* parasites that cause disfiguring sores (Figure 4) which fester for many months and require long-term medication. Some forms of the infection go to the liver and can be fatal. More than a thousand US personnel have contracted leishmaniasis during ongoing Operations Enduring Freedom and Iraqi Freedom.[44] Unfortunately, the types of insecticide sprays that normally control mosquitoes are generally ineffective against sand flies. To address this threat, DWFP grants were channeled, by competitive award, via the Entomology Division at the Walter Reed Army Institute of Research to facilitate intensive field studies of sand fly behavior and control. Although a series of research papers by Coleman, Burkett, and colleagues[45-47] have resulted, the sand fly biting problem has not been resolved. Consequently, efforts to understand how to improve the delivery of more effective insecticidal sprays are being reemphasized. Also, Warburg and colleagues[48] at the Kuvin Center of the Hadassah Medical School, Jerusalem, received a DWFP grant to develop measures to protect outposts against sand flies. These projects have revealed that sand flies often emerge from the soil beneath tents and camps. In an effort to prevent sand flies breeding in rodent burrows, the Genesis Company (Wellington, Colorado) won an award for producing insecticidal baits that would pass through specific rodent reservoir hosts of leishmaniasis to prevent breeding of sand fly larvae in their burrows. This approach is being developed with other feed-through treatments by Mascari et al[49-51] at Louisiana

*Project results unpublished to date

Figure 4. Examples of dermal leishmaniasis contracted in Iraq during Operation Iraqi Freedom. Note in the top photo that the area of the arm covered by the shirt sleeve is free of bites, demonstrating the value of simple measures in the prevention of insect bites.
(Photos courtesy of COL Russell Coleman, MS, USA)

State University for field testing against sand flies in Turkey.

Control of filth flies and house flies is best achieved by good sanitation, but this cannot always be ensured in deployment situations. One competitive DWFP award enabled Koehler[52] and military students in the Urban Entomology Unit of the Department of Entomology and Nematology at the University of Florida, Gainesville, to optimize some old countermeasures for fly control. For example, one student evaluated pesticides for residual treatments of various types of string and rope on which flies like to rest. He determined which combination of insecticide and string fiber would be most effective for use against flies in tented camps. Another student continues this line of experimentation by devising ways to drape loops of treated string over attractant traps to which flies are lured and killed. These masters level graduate students were supported by the US Navy's Medical Service Corps Inservice Procurement Program.[53] Another development from Koehler's team, invisible imidacloprid paint bait with attractant for killing flies quickly, was the first DWFP product to receive a National Stock Number from the Armed Forces Pest Management Board.

As the DWFP competitive grants program has grown, awardees have included entomologists at the US Centers for Disease Control, Division of Vector-Borne and Zoonotic Diseases, for development of natural pesticides extracted from agricultural waste. Other plant products that have insect repellent properties are under evaluation for insecticidal potency against flies, mosquitoes, and sand flies, while Scharf and Song[54,55] are exploring low molecular weight compounds that could serve as volatile repellents and insecticides for potential limitation of biting insects over a wide area.

Although the public perception of pesticides can be unfavorable, the facts are that the use of pesticides can be extremely effective against all sorts of pests and disease vectors. In an effort to investigate this dichotomy, one of the most original lines of inquiry funded by DWFP competitive grants has allowed Peterson and colleagues[56-61] at Montana State University, Bozeman, to undertake comparative risk analyses of the impact of pesticides. For a series of model scenarios involving vector-borne diseases such as malaria, West Nile fever, and plague, they carefully quantified the likely benefits of vector control by means of appropriate insecticide applications, versus possible disadvantages to the health of people and environmental impact. One particular study by Macedo et al[62] weighed the potential health benefits of vector control against the adverse consequences of likely exposure of deployed military personnel to pesticides used on clothing and bed nets, and sprayed around the camp. In all cases, the risk to humans was found to be minimal compared with the health benefits of avoiding vector-borne diseases.

Upgrading Defense against Diseases Transmitted by Insect Bites

While many useful products from DWFP research are already on the way towards production and supply for the public as well as deployed troops, the examples described above are far from sufficient to cover all our needs. Apart from combating mosquitoes and the various types of flies that transmit debilitating

infections such as malaria, leishmaniasis, dengue, and other arboviruses, there are many other noxious types of biting insects (bedbugs, fleas, lice, etc) and other arthropods (ticks, mites, scorpions, etc) that merit our concern. With nearly 5 years of progress in the DWFP program, however, our focus remains on the most dangerous flying vectors, particularly certain species of mosquitoes and sand flies. That focus is necessary until we have greatly improved methods and materials to protect our forces deployed to forward situations in all regions of the world from the threats of inconspicuous insect foes. This will allow those forces to more effectively deal with the challenges presented by the more obvious human enemies.

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COL DUNEMN JOINS THE *AMEDD JOURNAL* EDITORIAL REVIEW BOARD

The *AMEDD Journal* welcomes COL Kathleen N. Dunemn, AN, USA, as a member of the Editorial Review Board. COL Dunemn is Chief, Department of Nursing Science, Academy of Health Sciences, AMEDD Center and School, Fort Sam Houston, Texas, and the Nursing Education/Enlisted Training Consultant to the Office of The Surgeon General.

COL Dunemn joins the board replacing COL Patricia Patrician, AN, USA. COL Patrician has been a member of the Board since October, 2004. We thank COL Patrician for her dedication to the high standards and professional quality of this publication, and her years of service and support to our mission.

The Editors

Support of Far-Forward Disease Surveillance Operations with Deployable, Real-Time Vector-Borne Disease Agent Analytic Capability

Col James A. Swaby, BSC, USAF
James C. McAvin

The Vector Surveillance Analytic System (VSAS) is a portable, field-durable, field-sustainable, real-time, arthropod-borne agent detection platform used to support disease surveillance operations at far forward locations. The VSAS was originally developed to establish a DoD deployable methodology for dengue virus detection, but focus on system capability was redirected to *Leishmania* detection and deployed in August 2003 to support the Leishmaniasis Control Program (LCP) of the 520th Theater Army Medical Laboratory, Tallil Air Base (AB), Iraq.[1] The mobility of the VSAS allowed direct support to US Army Preventive Medicine and US Air Force Public Health *Leishmania* surveillance operations throughout the LCP area of responsibility. Force health protection support was provided at Camp Victory; Baghdad International Airport AB; Balad AB; and Kirkuk AB, Iraq; and Kabul, Afghanistan, from February to October of 2004.

The VSAS operates as a standalone field surveillance activity or as an extension of other deployable assets, such as the US Army Area Medical Laboratory or the Air Force Biological Augmentation Team. The field utility of the VSAS is clearly proven in diverse operational applications and environmental conditions; *Leishmania* surveillance Southwest Asia,[2] dengue surveillance at Joint Task Force Bravo, Honduras,[3,4] and with the Armed Forces Research Institute of Medical Sciences, Bangkok, Thailand.[5] It has also been adapted for use in the Arctic by NASA* in the development of genomics-based identification methodologies for the Haughton-Mars Project† on Devon Island in the Territory of Nunavut, Canada.

*National Aeronautics and Space Administration
†Information on the research project available at: http://www.marsonearth.org/

The VSAS addresses a requirement established by the Joint Program Executive Office (JPEO) for Chemical and Biological Defense for the development of deployable identification technologies for disease agents of operational significance.[6] The JPEO has designated *Leishmania* and dengue virus as threat agents (Block 1, Tier 2). To address that threat, testing is underway to incrementally establish VSAS technologies as subcomponents of the Joint Biological Agent Identification and Diagnostic System (JBAIDS), a JPEO/DoD accepted analytic system.

The VSAS is composed of:

1. Thermally-stable, hydrolytic enzyme resistant, freeze-dried, dual-fluorogenic, polymerase chain reaction (PCR) and reverse transcription-PCR (RT-PCR) assays and positive control template, genomic DNA and Armored-RNA® (Asuragen, Incorporated, Austin, Texas).[7,8]
2. Preformatted sample stabilization and processing materials.
3. Two-man transportable, field-durable, real-time PCR instrumentation: the Ruggedized Advanced Pathogen Identification Device (RAPID®) (Idaho Technology Incorporated [ITI], Salt Lake City, Utah).

Assay primer and probe oligonucleotides are designed de novo, and freeze-dried PCR reagents are manufactured by ITI.[2,3] Assays are prepared using an ITI proprietary formulation that is formatted to standardized PCR and RT-PCR thermal cycling protocols. The ITI vector surveillance reagent kit is preformatted with color coding to simplify preparation. Freeze-dried assays only require hydration and addition of sample template prior to analysis. The thermal-stable property of the assays eliminate the

need for a -20°C cold chain that is typically required for PCR reagents, thus vastly enhancing the mobility of the system. It also eliminates cold storage and resupply requirements that are unacceptable under far-forward deployed conditions.

Arthropod nucleic acid extracts are prepared with a commercially available, off-the-shelf, thermally stable, preformatted, guanidinium thiocyanate based total nucleic acid (DNA and RNA) purification kit, QIAamp Viral RNA Mini Kit (QIAGEN, 27220 Turnberry Lane, Valencia, California 91355). Extract is prepared following the manufacturer's spin protocol with the exception that the carrier RNA step is not implemented, thus eliminating the need for a 4°C cold chain. Also, centrifugation steps are adapted to the RAPID mini centrifuge, eliminating the need for a tabletop centrifuge. This kit has been adopted because of its field-worthiness and its capability to extract total nucleic acid in a standardized, single protocol which is applicable to organisms harboring either RNA or DNA genomes. Two other advantages of the kit are the lysis buffer, "Anschlagpuffer Virus Lysis" (AVL), which has been shown to inactivate infectious agents,[9] thus providing an additional level of safety when processing samples, and the genomic RNA template, which has been shown to remain stable in AVL at ambient temperatures (25ºC to 37ºC) for days to weeks. The kit efficiently purifies nucleic acid from diverse matrices, to include mammalian body fluids and tissues and arthropod homogenate.

The Ruggedized Advanced Pathogen Identification Device.

The RAPID PCR thermocycler, is a real-time fluori-meter with a closed capillary design and 32-sample capacity.[10,11] The thermocycler is operated by a laptop computer with programmable PCR cycling conditions. Data management is automated. The RAPID mini centrifuge is used for sample preparation and capillary loading. The RAPID thermocycler is the commercialized version of the JBAIDS thermocycler. Since the technologies of these thermocyclers are essentially identical, assays can be readily transitioned from one instrument to the other.

The VSAS, including several hundred assays and sample processing materials, are transported in 2 hardened, waterproof cases (63 × 49.2 × 35.2 cm). The VSAS is routinely transported as personal equipment on military helicopters or fixed-wing aircraft, or transported on commercial airlines as baggage. Ground transportation is by light vehicle or carried manually. The small footprint of the VSAS allows configuration on a truck tailgate with the system powered by a 110V or 220V source, usually an electric generator, or, if necessary, the 12V battery of a vehicle with the engine running. The efficiency of preformatted reagent and sample preparation kits, along with the closed capillary design of the RAPID, permit sample processing and master mix preparation to be conducted without a biological containment hood or spatial separation. However, in order to tailor protective measures to the surveillance requirements, appropriate operator personnel protective equipment must be provided and personnel made aware of which vector(s) will be recovered. System configuration requires about 10 minutes, and sample processing and analysis less than 2 hours.

The VSAS provides deployable analytic capability for real-time vector-borne disease risk assessment. This is paramount in affecting time-critical and focused disease prevention and control measures. This is especially relevant to leishmaniasis and dengue fever because, in the absence of a vaccine or prophylactic drug, the only means of protecting deployed military personnel is the prevention of bites by infected arthropods. Prevention and control of transmission is most effectively achieved through heightened awareness of the need for personal protective measures, and by reduction in vector populations. Focused application of insecticides and elimination of breeding habitat in areas where the risk is greatest—

where infected vectors and breeding populations are found—are the most effective uses of vector control resources to reduce transmission.[1,2]

The Armed Forces Pest Management Board (AFPMB) has approved Leishmania genus (LEIS) and visceral genotype (LVL) PCR assays as DoD accepted methodologies for Leishmania vector surveillance. The VSAS dengue RT-PCR assay (DU-JCM) was submitted to AFPMB in February 2008. The LEIS, LVL, and DU-JCM assays will be submitted concurrently to the JPEO for approval as candidates for clearance by the US Food and Drug Administration on the JBAIDS. Additional assays of operational significance are in development.

The VSAS is a joint US Air Force, Army, and Navy product developed through a Cooperative Research and Development Agreement with ITI, the JPEO primary contractor.

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The Vector Surveillance Analytic System operating in the field environment in Thailand during August 2007.

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Level III Preventive Medicine in a Counterinsurgency Environment

MAJ Derek J. Licina, MS, USA

ABSTRACT

As the Department of Defense moves forward to secure Baghdad, military forces are being strategically dispersed in very austere environments. These forces live and work side-by-side with their Iraqi counterparts in an effort to clear, hold, and reconstruct the city block by block, and further separate the insurgents from the general population. Level II preventive medicine (PM) personnel directly support these forces and keep them in the fight by reducing acute illness and disease and nonbattle injuries. Level III PM is performing the traditional PM mission of reducing both acute and chronic illness while conducting Deployment Occupational Environmental Health Surveillance and supporting Level II PM. However, the doctrinal basis of Level III allocation and priorities of core competencies have shifted. Are we meeting the need? This article attempts to answer the question based on experience as a Level III PM detachment commander in Baghdad, and provide recommendations for change across the spectrum of the Army's structure of doctrine, organizations, training, materiel, leadership, education, personnel, and facilities.

BACKGROUND

"What kind of war do you prepare for when you cannot prepare for them all?" Andrew Krepinevich poses the question in his analysis of the US Army before, during, and after a counterinsurgency in Vietnam.[1] The question has resurfaced as the Army again finds itself operating in a counterinsurgency in Iraq. Has the Army as an institution learned and implemented change based on experiences in the Philippines during the early 20th century, or Vietnam, Lebanon, and El Salvador in the latter part of the same century? Are we trained and equipped to contribute toward an overarching US government strategy addressing underlying factors of an insurgency? Although the broader questions have been debated and recommendations published, the role of preventive medicine (PM) in support of counterinsurgency operations has not.

Counterinsurgency is, by definition, "Those military, paramilitary, political, economic, psychological, and civic actions taken by a government to defeat an insurgency."[2] The recently published Army *Field Manual 3-24: Counterinsurgency*[3] emphasizes political, social, and economic programs as more valuable than kinetic force in addressing the root cause of an insurgency. In the absence of legitimate governments providing for the population, insurgents deliver essential services such as water, electricity, sanitation, and medical care. Hezbollah exemplifies this characterization in the care and services they provide for the Lebanese population in exchange for individuals to fill their militia ranks. This pattern replicated itself in the streets of Baghdad, as observed by then MG Peter Chiarelli.[4] He found "…anti-coalition and antigovernment religious rhetoric originated from those areas of Baghdad characterized by low electrical distribution, sewage running raw through the streets, little to no potable water distribution, and no solid waste pickup.…a direct correlation existed between the level of local infrastructure status, unemployment figures, and attacks on US Soldiers." MG Chiarelli studied these underlying factors and achieved success by focusing reconstruction and employment efforts on sewage, water, electricity, and trash removal—what he called "SWET." Three of these 4 services make up core competencies of Army PM personnel. Is PM currently being leveraged in Iraq, Afghanistan, and the Horn of Africa to contribute toward the overall strategic effort? That is debatable. Are they formally trained in counterinsurgencies and doctrinally established to meet the demand? Not really.

APPLICATION OF CURRENT DOCTRINE

Doctrine for Level III PM detachments is driven by multiple Department of Defense (DoD) Directives and Instructions, Army Regulations, Department of the

Army Pamphlets, and myriad Field Manuals. The most robust description of duties and responsibilities is found in *Field Manual 4.02-17, Preventive Medicine Services*,[5] which was last updated in August 2000. It highlights Level III support in the areas of medical threat analysis, health hazard assessment, disease and nonbattle injury (DNBI) surveillance, health physics surveys, disease-vector identification, environmental health assessments, and field sanitation team training, among other operational capabilities. These areas are relevant in both permissive and nonpermissive environments, though their overall priority may shift. PM services in stability, support, and civil-military operations are discussed in *Field Manual 4.02-17* and more accurately describe what contributions PM can make in a counterinsurgency.

During the 2007 surge in operations in Baghdad, the 61st Medical Detachment provided Level III support to the multinational divisions in Baghdad and central Iraq which were engulfed in a counterinsurgency. Over 70,000 US, Coalition, contractor, and third country nationals supported operations in this nefarious battle space. Doctrinally established to support 17,000 personnel, the 61st Medical Detachment in reality performed the mission of 4 detachments. They provided support in an area over 80,000 km^2, including 20 forward operation bases (FOBs), 70 joint security stations (JSSs) and combat outposts (COPs), and the Victory Base Complex, which is equivalent to a midsize municipality in the United States. Doctrine states that Level III PM is 100% mobile, however, during the counterinsurgency in Iraq, this has only been true on the FOBs to which they were assigned. Moving between FOBs requires external support such as uparmored* vehicles, helicopters, and stalwart security. The criteria for this doctrinal basis of allocation should be further explored. New criteria such as the number of Level II PM assets supported, or type of conflict (counterinsurgency, peacekeeping, or disaster response/humanitarian assistance) could be added and weighted to determine operational needs on the ground.

During the Operation Iraqi Freedom (OIF) 06-08 rotation, the 61st Medical Detachment executed a majority of these doctrinal tasks. Prior to deployment, a medical threat profile based on hazards in the area of operation was developed. Not considered during this analysis were diseases that could be brought into theater by Coalition forces and contract partners who may not require stringent predeployment health screening. Round worm infections and bed bug infestations among employed third country nationals providing services to Coalition personnel were not uncommon.

Health hazard assessments were conducted to characterize exposure to the omnipresent dust, smoke from burning solid waste, and diverse chemicals. As the war spiraled into a counterinsurgency, Coalition forces moved into urban environments in and around Baghdad to establish JSSs and COPs. These locations were based among existing infrastructure where running water was intermittent and solid waste disposal nonexistent. This posed increased risk to Coalition personnel performing personal hygiene using local water, defecating in improvised containers, and living next to solid waste burn pits used to eliminate trash and decrease the rodent and vector populations. Level II PM provided direct support to these austere sites which rapidly grew in number. Occupational Environmental Health Surveillance at these locations was limited due to time, the daily enemy threat, and competing acute health priorities.

Doctrinally, surveillance for disease and nonbattle injury (DNBI) is the responsibility of Level III PM. Unfortunately, or fortunately depending upon perspective, the 61st Medical Detachment did not monitor DNBIs. An excellent rapport was established with the Theater Medical Command PM physician who monitored DNBIs and notified the 61st Medical Detachment of patterns or trends within their area of operation. This allowed Level III PM to focus energy on prevention while knowing any spike in illness would be identified and collaboratively addressed in a timely manner. Unfortunately, this method builds dependency and reduces recognition and assessment skills that could be employed in a counterinsurgency environment when working with host nation security forces or the local civilian population.

Meeting the Need in a Counterinsurgency

These are just a few examples of how Level III PM addressed doctrinal tasks during a counterinsurgency.

*Military vehicles which have been reinforced with additional armor to counter the affects of roadside and buried bombs, and improved penetrating direct fire munitions.

There are other examples where the Army could learn from Level III successes and failures to drive change. The Army uses "doctrine, organizations, training, materiel, leadership, education, personnel, and facilities (DOTMLPF)" as "a problem-solving construct for assessing capabilities and managing change."[6] Recent experience in Iraq and a reflection on previous counterinsurgency operations provide justification to stimulate change within the PM field using the DOTMLPF construct.

Doctrine

The global shift of populations toward urban areas and the inability of governments to provide basic services fuels insurgent efforts to exploit the disenfranchised.[4] Counterinsurgencies are built to address these groups and underlying factors. Such operations are "a long, slow process that requires the integration of all elements of national power…to accomplish the tasks of creating and supporting legitimate host governments that can then defeat the insurgency."[7] The Viet Cong understood the power of PM and employed sanitation extensively in their civic action and propaganda efforts. They used slogans such as "Prevention of Disease is Patriotism" and "Prevention of Disease is Fighting the Americans."[8] Dr Richard Carmona, the US Surgeon General, reflected on his time as a Special Forces medic during the war in Vietnam: "PM is probably the most important thing I learned…not only was I responsible for the health care of my team, but for an entire village as well!"[9] Both sides realized interactions between Soldiers and indigenous populations provided opportunities to make positive impressions and obtain support from the population.[10] In the current situation, the shortage of international and nongovernmental organizations in Iraq means that military forces possess the only readily available capability to support the needs of the population.

Current civil-military operations (CMO) doctrine mentions building host nation capacity and local sufficiency in the areas of health education, water supply, and waste disposal.[5] These areas are ripe for intervention by Level III PM working through, by, and with host nation counterparts to fill the void in essential services, provide legitimacy to the government, and stimulate the economy through job creation. Understanding these capabilities, the 61st Medical Detachment and the Multinational Corps-Iraq Force Health Protection Officer reached out to the Corps CMO staff. Discussions acknowledged that Provincial Reconstruction Teams (PRTs) and Civil Affairs (CA) units have no organic PM equipment and should coordinate with PM detachments for support.[5,11] Offers were made to have the 61st Medical Detachment advise, coordinate, and evaluate public health resources within their respective areas of operation to advance host nation services provided to the population.[12] Conceptual agreement was achieved and laudatory comments made, however, strategic support was not provided. They requested that the subject be revisited in the future, but short term tactical needs dictated that Level III PM pursue other avenues of support. As of this writing, the 61st Medical Detachment is working with the 1st Calvary Division G9 CMO staff to address the significant void in public health and sanitation. Progress is slow. The omnipresent challenges of PM units engaging PRT and CA personnel may be rooted in CA and PM indoctrination courses, which is explored later in this article.

Organizations

The history of PM efforts highlight different, yet synergistic capabilities between veterinary and preventive medicine personnel, which could be employed in Iraq and future counterinsurgencies. For example, when millions of Pakistanis were displaced from their homes, a major relief effort was mounted by PM physicians, a PM company, and 42 enlisted personnel.[13] This was not the 2005 earthquake disaster response in Pakistan, rather the relief effort following the flooding of the Brahmaputra River in 1954. In 1963, a team of 4 physicians, 3 sanitary engineers, an entomologist, and 8 PM technicians administered 41,000 doses of typhoid fever vaccine, deloused 9,000 people, and treated 75 wells following intense flooding in Morocco.[14] Army Veterinary Corps officers actively participated in the Medical Civic Action program in Vietnam where they prevented zoonotic diseases and provided treatment and care to domestic animals.[15] Unfortunately, current organizational structure within veterinary and PM communities does not leverage capabilities; rather, the structure fosters competition in accomplishing similar goals.

In an effort to reduce perceived and actual food and water inspection overlap, serious consideration should be given to merging the Veterinary Food Inspection Specialist (military occupational specialty (MOS)

68R) and PM Specialist (MOS 68S). Title the new specialty "68RS, Public Health Specialist" and establish doctrine and training to meet the future need. Experts in both fields have vacillated over this concept for years. Unfortunately, to date there has been little recognition of the immediate and future application of creating a more dynamic Soldier to meet tactical and operational needs in counterinsurgency missions.

Building upon the public health synergy of the new 68RS MOS, the organizational structure of Level III PM could be changed to enhance the efficiency and effectiveness of their efforts. The current Modified Table of Organization and Equipment* (MTOE) assigns 13 personnel to the detachment as shown in Figure 1. Increasing the MTOE to 14 assigned with 3 additional designated personnel to be added during deployment (similar to the function of the Professional Officer Filler Information System[16]) as shown in Figure 2, could greatly enhance the detachment's capabilities in a counterinsurgency.

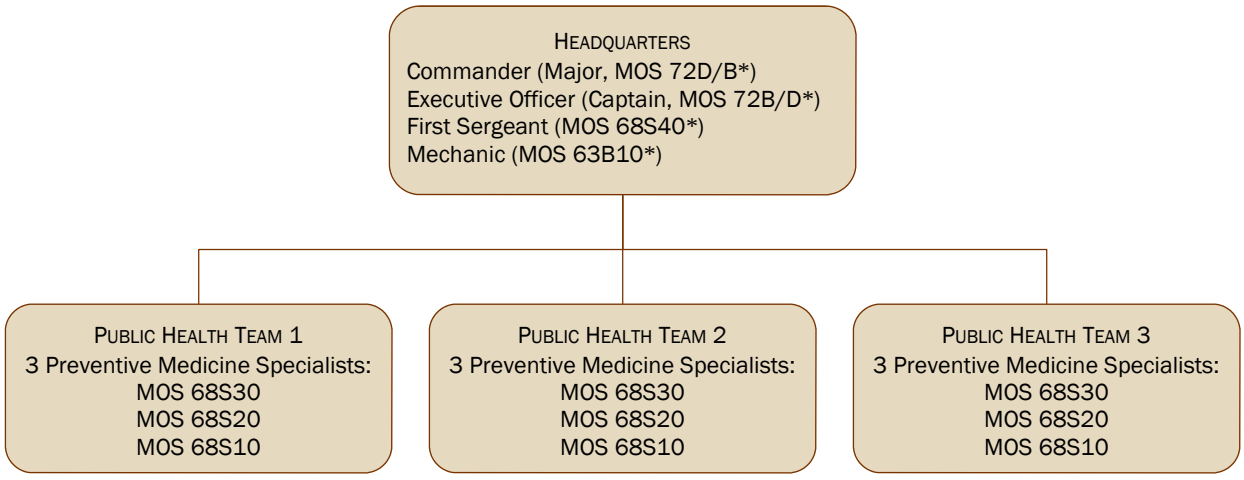

Figure 1. Current US Army Modified Table of Organization and Equipment personnel allocation for the Level III Preventive Medicine Detachment.

*MOS (military occupational specialty) glossary:
72B Entomologist
72D Environmental Science Officer
68S Preventive Medicine Specialist
63B Light-Wheel Vehicle Mechanic

Veterinary medical care is provided to Coalition military and contract working dogs in Iraq, however, minimal engagement with indigenous animal populations is occurring. Team 4 of this conceptual medical detachment could address host nation food production, provide animal husbandry training, and support vaccination and zoonotic disease surveillance programs. One can argue that these missions are part of existing veterinary doctrine, but they are not being performed in Iraq.[17] Colocating PM and veterinary medicine assets on the same forward operating base may facilitate coordination, but assigning both specialties to a PM detachment would synchronize these capabilities toward a common goal. Conversely, this concept could be applied to a veterinary detachment by adding an Environmental Science/Engineer Officer (MOS 72D/E) and Public Health Specialists (MOS 68RS) to their MTOE.

Additionally, the Medical Laboratory Specialist (MOS 68K10) would bring a comprehensive laboratory capability for the analysis of food, water, tissue, blood, and body fluid. Based on the experiences with legionella, Methicillin Resistant Staphylococcus Aureus, tuberculosis, Q-fever, and suspected cases of leishmaniasis, histoplasmosis, salmonella, *E. Coli*, and other illnesses during the OIF 06-08 rotation, the Medical Laboratory Specialist must be qualified to test for some of these and other infectious agents found in austere environments. The Medical Logistics

*Defines the structure and equipment of a military organization or unit.

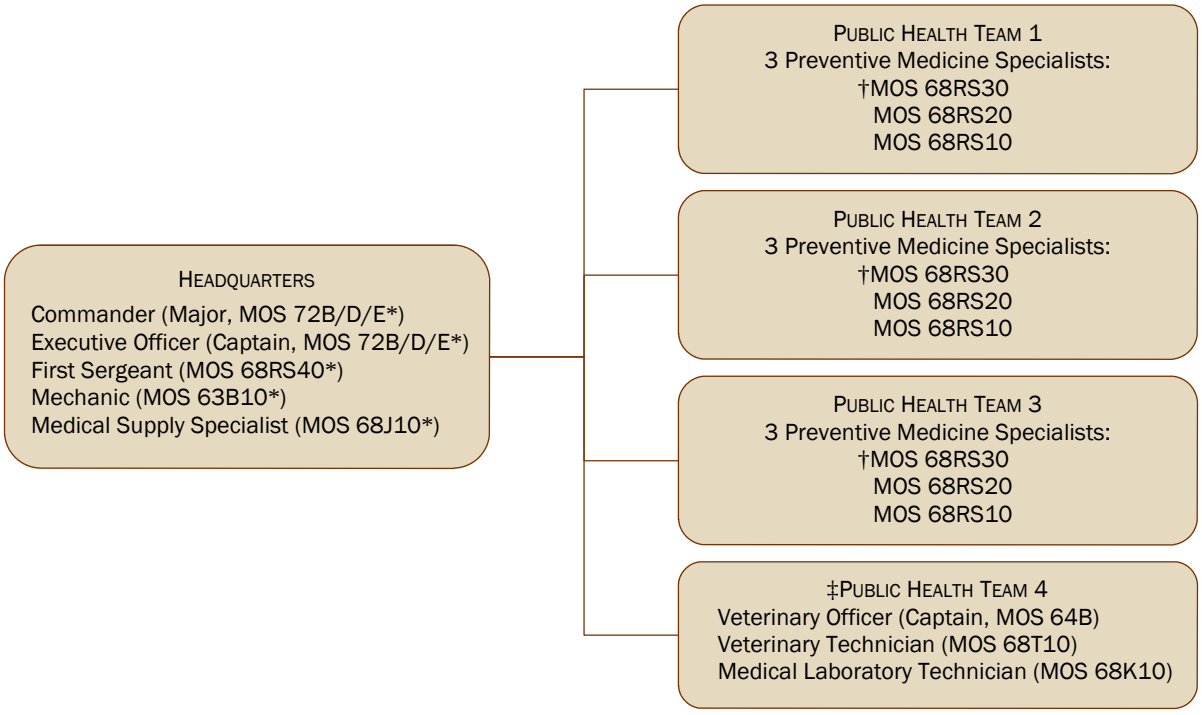

Figure 2. Current US Army Modified Table of Organization and Equipment[§] personnel allocation for the Level III Preventive Medicine Detachment.

*MOS (military occupational specialty) glossary:
72B Entomologist
72D/E Environmental Science/Engineer Officer
68S Preventive Medicine Specialist
63B Light-Wheel Vehicle Mechanic

†The conceptual 68RS MOS would be created as a merger of existing MOSs 68R, Veterinary Food Inspection Specialist, and 68S, Preventive Medicine Specialist.

‡Team 4 is envisioned as Army Medical Department Professional Officer Filler System (PROFIS) staffing billets. PROFIS predesignates qualified Active Duty health professionals serving in Table of Distribution and Allowance** units to fill Active Duty and early deploying and forward deployed units of Forces Command, Western Command, and the medical commands outside of the continental United States upon mobilization or upon the execution of a contingency operation.[16]

§Defines the structure and equipment for a military organization or unit.

**Prescribes the organizational structure, personnel and equipment authorizations, and requirements of a military unit to perform a specific mission for which there is no appropriate table of organization and equipment.

Specialist (MOS 68J10) could manage all classes of supply for this new detachment. A PM Specialist currently performs logistics duties which draws time and effort away from the PM mission. Assignment of a Medical Logistics Specialist to the MTOE to manage unit logistics would liberate the Public Health Specialists to perform their public health mission. Collectively, these changes would eliminate redundancy, increase efficiency, and assist host nations in meeting public health needs.

Training

Four years into the Iraq counterinsurgency, the PM community continues to focus support internally on Coalition assets rather than externally on the civilian population and Iraqi Security Forces. This lack of public health integration exists for many reasons, some within and others outside of DoD's control. Institutional training provides fertile ground to increase this capacity.

Table 1. Common core/science track counterinsurgency related classes taught in US Army Course 6AF5 - Principles of Military Preventive Medicine.

Title	Hours
Army HIV Program	1
Introduction to Humanitarian Assistance Operations	1
Malaria Prevention	1
Preventive Medicine Support for Disasters	1
Population Health	1
Disaster Relief Practical Exercises	2
Nutrition Concerns in Disaster Relief	2
Preventive Medicine Aspects of Detainee Operations	2

All Army PM officers attend the Principles of Military Preventive Medicine indoctrination course. The program of instruction (POI) consists of 585.4 hours of common core, clinical, and science track instruction.[18] A review of the common core and science track courses which are completed by nonclinicians reveals that only 11 hours (3%) are focused on material directly or indirectly related to counterinsurgencies (Table 1).

Although other classes, such as water quality analysis, develop competencies which can be applied in counterinsurgencies, these classes do not draw correlation between the two. Further analysis revealed 14 hours of instruction (Table 2) provided during the clinical track relate to counterinsurgencies. These classes should be incorporated into the common core track to increase the capabilities of all PM officers. Serious consideration should be given to adding courses highlighting root causes of counterinsurgencies and effective employment of Army PM in support of civil-military operations.

Concurrent with changes in training delivered within the AMEDD POIs, further development of external training must also be addressed. As previously indicated, aggressive efforts were made by the 61st Medical Detachment to engage CA personnel, with little return on investment. This limited success was certainly not due to a lack of effort, rather, the difficulties were a result of what was routinely observed as a lack of education. CA officers in theater understood the significant impact water and sanitation have during a counterinsurgency. Unfortunately, discussions with both seasoned and new CA Officers revealed that they had received minimal training on how to leverage PM in bridging public health gaps. CA doctrine discusses PM, but what emphasis is placed on this battle operating system during initial training is unknown to the author.[12] A comprehensive analysis of their course POI could identify where training deviates from doctrine, and how Army PM could provide training assistance. Cross-training CA and PM personnel could create a symbiotic relationship yielding substantial dividends during counterinsurgencies.

Recent experiences in Iraq continue to identify profound shortfalls in the Army Field Sanitation Team (FST) program.[19] The program is conceptually accepted by all levels of command, but implementation is lacking. Many perceive the FST course as nothing more than an avenue to obtain enlisted promotion points. Team members are assigned on paper but lose currency or complete the task only if time permits. Most unit commanders do not procure FST equipment due to high costs, other priorities, and time. The establishment of a single National Stock Number to streamline the FST kit would reduce the time spent tracking numerous line items found in the current kit and increase commander compliance. Army medics adopted the FST responsibility in Iraq with direct support from Level II PM personnel. Is it more practical to add FST classes to the Army medic POI

Table 2. Clinical track counterinsurgency related classes taught in US Army Course 6AF5 - Principles of Military Preventive Medicine.

Title	Hours
Rapid Health Assessment	1
Public Health Assessment	1
Civil Affairs and Foreign Government Liaison	2
Implications of Emerging Infectious Diseases	2
Preventive Medicine Support in Contingency Operations	8

and have them assume the mission? This may be a desirable situation upon which the Army should capitalize.

A net gain in FST training was made by the 61st Medical Detachment during OIF 06-08. The decision to shift training from Coalition members to the Iraqi Security Forces was made upon arrival, and consensus was reached at the strategic level to replicate this effort throughout theater. Training host nation military and civilian populations in PM is essential to sustain their fighting force and build basic sanitation capacity. Cultural implementation of these newly acquired skills will not occur overnight, but they are essential in meeting short and long term needs of the population.

Materiel

Coalition personnel in Iraq are working alongside the ISF and operating out of austere joint security stations. Level III PM is supplying some of those stations and Army-led Military Transition Teams with basic FST equipment to meet urgent needs in controlling vectors and purifying water. Despite the regulation requirement for supplies, they do not have the resources on hand for many reasons.[20] It should be assumed that similar scenarios will exist in future counterinsurgencies and Level III PM must be equipped with additional kits to support those in need.

Insurgents will continue to pursue the use of toxic industrial chemicals and weapons of mass destruction. Increasing the Level III detachment's direct chemical reading capability to measure contaminant levels is a critical requirement. The INFICON (Two Technology Place, East Syracuse, New York 13057) HAPSITE® gas chromatograph/mass spectrometer, and Smiths (Smiths Detection, 21 Commerce Drive, Danbury, CT 06810) HazMatID™ portable chemical identifier used by the Army Area Medical Laboratory and Navy Forward-Deployed Preventive Medicine Unit provide this much needed capability. Neither of these Level IV PM units were in theater during OIF 06-08, which placed higher expectations upon Level III PM to execute missions they were ill-equipped to perform.

Leadership

The current Army PM leadership was shaped by experiences during the first Gulf War (1991) and the Balkan deployments—a conventional war and peace keeping operations. Much of their work led to the development and implementation of the Occupational Environmental Health Surveillance (OEHS) program which is easily implemented in a linear battlefield and semipermissive environment.[21-23] This program captures data to analyze acute, chronic, and delayed health effects, primarily through air, soil, and water sampling.[23]

Recent events in Iraq led to reprioritizing the acute public health needs over the OEHS sampling mission. OEHS results from the US Army Center for Health Promotion and Preventive Medicine (CHPPM) were provided to the 61st Medical Detachment, on average, 91 days after sample shipment for air, 52 days for soil, and 59 days for water. Level II PM experienced similar turnaround times resulting in a de-emphasis on OEHS sampling in lieu of addressing acute needs using real time analysis equipment. This was counterintuitive for some Level II PM officers who perceived OEHS air, soil, and water sample collection as their primary mission and lifeline to definitive answers. The PM community and leadership must address the OEHS sampling and documentation requirement in a counterinsurgency environment with resources currently available. It may be more realistic to have Level II and III PM personnel conduct initial base camp OEHS sampling within their areas of operation and Level IV PM conduct routine and base camp closure OEHS sampling in conjunction with the Army Corps of Engineers. Serious discussion must also address this requirement and how PM measures effectiveness. One could argue that OEHS sampling does not tie directly to DNBI statistics which is the current default measure of PM success or failure.

The effectiveness of Level III PM detachments in the field is directly dependent on Soldiers that the Army recruits, develops and places in positions of leadership and command. In the final analysis, without dedicated, intelligent, well-trained, professional leadership, none of the other factors discussed herein will matter in the performance of these detachments. Leaders in higher command positions must have the full spectrum of insight and understanding as to the capabilities and ultimate, long-term strategic value represented by the Level III PM resource. Only then will the assets be intelligently applied and adequately supported. That command perspective comes from education and training in the strategic considerations of counterinsurgency operations, combined with the insights and understanding that only result from actual

experience developing and employing the Level III PM resources.

Over the next 5 to 10 years, leaders within the PM community will draw upon observations and lessons learned during the Balkan deployments and initial phases of OEF and OIF. Over the long term, Level II PM personnel currently serving in Iraq will assume leadership roles. Their counterinsurgency experience will likely drive changes in core competencies, with an emphasis on acute and general public health intervention, to meet what is perceived by many as the conflict of the future.[7,24,25]

Personnel Recruitment

Level III PM detachments are commanded by field grade Entomologist (MOS 72B) and Environmental Science/Engineer (MOS 72D/E) officers, which make these 2 specialties of particular interest in assessing recruitment and retention. The Army objective force for these officers is 346, with a current strength of 335 (97% fill). From 2004 to 2006, the objective force for these professions was 72 officers, of whom 61 (85%) are commissioned.[26] They joined through direct commissions following graduate school, college Reserve Officer Training Corps, or the US Military Academy. Some, like the author, convert to PM after serving as a Health Care Administrative Assistant (MOS 70B). Assuming that not all of the 61 commissioned officers will serve a career in the military could justify pursuing other recruitment avenues. A study assessing conversion trends from MOS 70B to the MOS 72 series may justify a marketing campaign to recruit these officers coming out of multiple OIF rotations. They would bring a first hand understanding of how PM can support the warfighter during a counterinsurgency.

Supporting the field grade Level III PM detachment commanders are company grade executive officers serving in these specialty areas. A review of active duty Army company grade Environmental Science/ Engineer officer authorizations revealed that half were in garrison assignments.[27] Forty-six percent of lieutenants and 53% of captains were assigned to field units, 26% and 25% respectively to CHPPM, and 28% and 22% respectively to Army medical centers or other organizations. In the perspective of an Army at war, this appears disproportionate to the current and future requirements. In 2006, the Army PM Consultant posed a salient question in the *Army Medical Department Journal*: "Should some MEDDAC ESO [medical department activity environmental science officer] positions be converted under current military-to-civilian initiatives in order to provide better developmental opportunities for junior officers elsewhere?"[28] It could be argued there is no better place to apply and develop skills than during combat deployments by conserving the fighting strength of those in harm's way. Reducing garrison positions could shift personnel to meet current PM shortages in deployable multifunctional medical battalions, and afford growth in areas such as newly activated civil affairs battalions and each regional special operations command. Experience in these assignments would generate skills necessary to effectively serve as both a Level III PM detachment executive officer and commander in a counterinsurgency environment.

Similar analysis should be completed to assess the proposed merger of the Veterinary Food Inspection Specialist (MOS 68R) and Preventive Medicine Specialist (MOS 68S) in the enlisted force structure. Ultimately, they will serve as Level III PM detachment members, NCOs, and detachment sergeants who execute the unit mission. It is imperative to solicit feedback from both recently returned and currently deployed PM and veterinary personnel, as they understand the current operational requirements. A comprehensive review of the manning document for the existing MOSs is necessary to shape future authorizations for the proposed Public Health Specialists (MOS 68RS). Other proposed changes, such as replacing the current MOS 68S level 10 (Private First Class through Specialist) at each Army brigade with a MOS 68S level 30 (Staff Sergeant), must be considered, since these positions will drive manning requirements.[29]

Personnel Retention

Numerous media outlets discuss the potential impact of high operational demands on retention. According to the DoD, "Army, Navy, Marine Corps, and Air Force met or exceeded overall retention missions."[30] What is not clear are retention rates in the PM community. Unlike most officers who enter Army PM with a degree related to their chosen field, and with the intention of directly applying that education, enlisted PM personnel are selected and trained by the Army in various skill sets necessary for their MOS. At specific points in the enlisted career path, the Army offers additional training of increasing sophistication to

support their respective specialties. However, the Army also regularly offers opportunities and incentives for Soldiers to change to another MOS specialty altogether, depending on staffing priorities and shortfalls at the time. Any Soldier considering a long-term career in PM will evaluate opportunities in their field against those opportunities represented in another MOS or civilian life, and make a rational decision. With low promotion rates to Sergeant First Class (grade E7) and above, due in part to the scarcity of senior PM level positions, this weighs heavily in the minds of Staff Sergeants (grade E6). These NCOs typically have 10 years in service and debate whether to continue their profession, reclassify, or leave the military. Unless the PM enlisted authorizations are adjusted to support and encourage the pursuit of careers by our enlisted Soldiers, the effectiveness and manning of Level III PM will be less than optimum. Increasing senior level enlisted PM authorizations allowing for professional growth commensurate with time invested could make a difference. Adding Master Sergeant (grade E8) positions to combatant and other strategic commands where Environmental Science/ Engineer officers currently serve would be a force multiplier, allow for professional growth and promotion, and positively impact retention rates. Additionally, investing in the long term education of both may provide an impetus to serve a career in uniform.

The Army PM leadership took the initiative in 2004 and crafted an education and training program by sending Environmental Science officers to the Uniformed Services University of the Health Sciences to complete a one-year Master of Public Health degree followed by a one-year utilization tour in Washington, DC. These officers can specialize in areas such as international health which has applicability in both disaster response and counterinsurgency operations. Upon graduation, the officer could work at DoD or military service headquarters levels, or other governmental agencies, such as the Department of State or US Agency for International Development, applying their skills to real world requirements. Assignments in other agencies broaden their understanding of interagency operations and meet the intent of *DoD Directive 3000.05, Military Support for Stability, Security, Transition, and Reconstruction Operations*[31] and the *Quadrennial Defense Review*.[25]

Facilities

Proposed consolidation of all services' enlisted medical training at Fort Sam Houston, Texas as part of the Base Realignment and Closure process is commended and should be replicated among other medical specialties. Consolidation of training efforts could reduce duplication in facilities, operations and maintenance costs, and personnel required to conduct similar training programs at 3 different service institutions while increasing productivity and developing a joint PM service member. Experience in Iraq highlights similarities in capability between Air Force, Army, and Navy professionals performing PM tasks. Current doctrine drives requirements for each service where the Navy traditionally focused on maritime operations, the Air Force on wing support, and the Army on the foot Soldier. In the counterinsurgency environment of Iraq, Navy Environmental Health officers are collocated on forward operating bases with Army Soldiers. Air Force Public Health and Bio Environmental Engineer officers/technicians are working shoulder to shoulder with Army personnel on large air bases. The 61st Medical Detachment provided general area PM support to all service personnel within multinational divisions in Baghdad and central Iraq during the OIF 06-08 rotation. Additionally, all 3 services received OEHS equipment and laboratory support from the US Army Center for Health Promotion and Preventive Medicine for the OEHS mission while deployed in Iraq. It is imperative that leaders within each service recognize the similarities in capabilities and requirements to develop a common set of knowledge, attitudes, and beliefs for a joint service PM training platform. This platform should be institutionalized at a consolidated PM training facility at Fort Sam Houston.

CONCLUSION

The *2006 DoD Quadrennial Defense Review* states:

> …the ability to wage irregular and unconventional warfare and the skills needed for counterinsurgency, stabilization and reconstruction, military diplomacy, and complex interagency coalition operations are essential.[25]

Adoption and implementation of the aforementioned DOTMLPF changes could facilitate transformation within the PM community to meet these current and future demands, and directly support overarching US government efforts in rebuilding essential services in

fragile societies. As recently observed in Iraq, and highlighted by the *National Security Strategy* signed by President George W. Bush:

> Military involvement may be necessary to stop a bloody conflict, but peace and stability will last only if follow-on efforts to restore order and rebuild are successful.[32]

Preventive Medicine can support both undertakings.

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44th Medical Command

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Preparing the Force for the Chemical, Biological, Radiological, and High Yield Explosives Battlefield; Today and Tomorrow

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The Chemical, Biological, Radiological, and High Yield Explosives (CBRNE) Sciences Branch* provides training to a diverse group of students, including members of the various US military services, foreign students, and civilians on medical operations on the nuclear, biological, chemical, or directed energy battlefield; as well as the safe use of radiation and radioactive materials. In 2007, the CBRNE Sciences Branch taught the 5-day Tactical Radiological Operations (TRO) Course at the Idaho National Laboratory, Idaho Falls, ID. The TRO course was developed and has evolved in response to lessons learned after 4 years of deployments in support of Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF). The gap analysis suggested that traditional health physics training designed for hospital and garrison environments did not provide the instruction and focus that Nuclear Medical Science Officers need when dealing with radiological hazards in nonmature theaters of operation.

The regulatory constraints on the use of licensed radioactive material limit the ability of the Army Medical Department Center and School (AMEDDC&S) to provide real world situations where health physics training would more closely replicate deployment and homeland defense scenarios. At the Idaho National Laboratory, the Department of Energy was able to provide, at one location, access to a unique combination of facilities, radioactive materials, and trained professional staff that cannot be duplicated at any Department of Defense facility. In order to bridge training gaps, the CBRNE Sciences Branch and the US Army Chemical School coordinated with the Idaho National Laboratory to accommodate OEF and OIF scenario-driven environmental health physics training for military personnel. The TRO course consists of didactic health physics training, radiation detection/ identification equipment training, high energy radioactive source identification and quantification, and radiological dispersal device training that culminated with a field training exercise incorporating basic military skills and team technical skills. It is also designed to facilitate small team training and interaction with training scenarios to provide opportunities for both individual leadership development and team problem solving.

Across the Army manpower structure, there are many different military occupational skills that have similar military knowledge requirements. This is true for radiological operations for some medical, chemical corps, and engineering disciplines. In order to broaden the availability of quality subject matter experts to address multiple mission requirements for such specialists, the TRO course is offered for Environmental Science and Engineering Officers and Chemical Operations Specialists.

The 2007 scenarios included:

- Tactical movement of a survey team into a location to conduct a base camp assessment for radiological hazards
- High energy radioactive source identification and mitigation to include exposure guidance for personnel
- Decontamination of personnel exposed to weapons grade or other nuclear materiel
- Encounters with media personnel regarding potential radioactive contamination to military and host nation personnel

*Department of Preventive Health Services, AMEDD Center and School

The critical tasks accomplished were:

- Selection of the proper radiation detection/ identification equipment for a given mission.
- Proper operation of radiation detection/ identification equipment for a given mission.
- Design radiological survey using *Technical Guide 236A; Basic Radiological Dose Estimation – A Field Guide*,[1] and then brief the brigade commander.
- Conduct radiological survey of area to include soil, air, and water sampling.

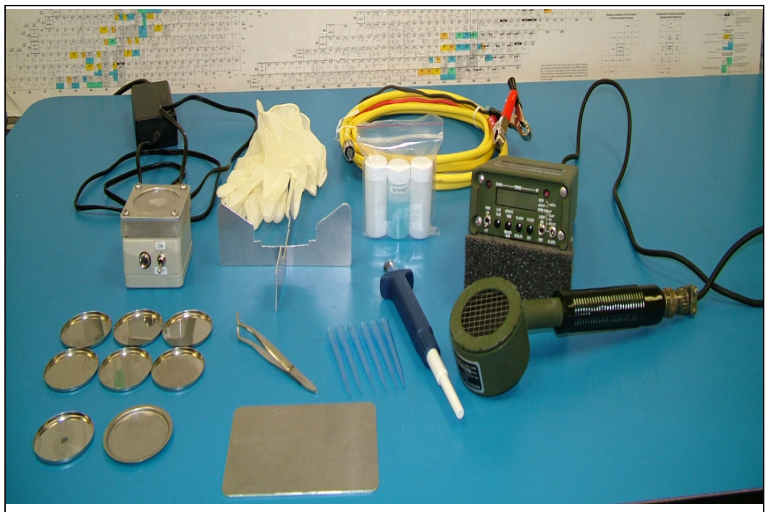
Testing and Fielding New Equipment

Recently, the CBRNE Sciences Branch participated in several meetings about the development of the new XM-329 Joint Chemical, Biological and Radiological Agent Water Monitoring System (JCBRAWM). The system is under development by the US Chemical Corps to augment the M272 Water Test Kit in response to the Army's identification of the need to expand the M272 capability to include the full spectrum of CBRNE threats. The requirement for expansion in capabilities is the result of recent threats in the areas of homeland security and homeland defense. The JCBRAWM consists of the AN/PDR-77 Radiac Detector Set which tests water for possible radiological contamination, the Hand Held Assay for possible biological contamination, and the standard M272 Water Test Kit for chemical contamination.

As the Nuclear Medical Science Officers and Preventive Medicine Specialists execute their wartime mission of base camp assessment, the enhanced capability provided by the JCBRAWM will further improve the safety and survivability of all Soldiers on the battlefield by ensuring that water sources are at an acceptable level of cleanliness and purification for consumption. In addition, it will increase the capability of the US Chemical Corps to identify which natural or manmade water sources should or should not be used for personal or equipment decontamination.

As a further complement to the type of equipment that will be used to sample and test water, the US Chemical Corps has enhanced the immediate personnel decontamination capability of the Army by developing the Reactive Skin Decontamination Lotion (RSDL). The new lotion provides a Soldier with the capability to perform on-the-spot decontamination without the necessity of the full spectrum decontamination line—a manpower intensive process. Through the use of the JCBRAWM and the RSDL, the Preventive Medicine Specialist will now have the ability to conduct on-the-spot chemical, biological, and radiological testing, with the added capability for personal and equipment decontamination.

Both AMEDD and the Chemical Corps will benefit from these recent new equipment developments. Even though JCBRAWM development testing is not complete, the CBRNE Sciences Branch will continue to represent the Army Medical Command in advising the developmental team to ensure optimum usability by Preventive Medicine Specialists.



Joint Chemical, Biological, and Radiological Agent Water Monitoring System (JCBRAWM)

A Standard of Proficiency for Fixed Medical Treatment Facilities in All-Hazards Response

A hazardous material incident involving CBRNE hazards or other threats, whether accidental or intentional, has the potential to produce catastrophic loss of life or property, or strike terror in the affected population. An incident may occur in the US or overseas. The Army Training and Evaluation Plan–Mission Training Plan for US Army fixed installation medical treatment facilities (MTF) provides hospital and clinic commanders and staff with a descriptive, mission oriented program to train the facility staff to perform its critical operations during such an event.

While US Army Medical Command directives, national healthcare standards, and local conditions and procedures dictate unique training requirements and performance standards, the Mission Training Plan describes many of the tasks that any staff of a hospital or clinic may be called upon to execute with a high level of proficiency. The commander of each facility is not expected to train on every single task in the Mission Training Plan; rather, tasks are selected and prioritized based on an assessment of an MTF's strengths and weaknesses, and on those tasks that focus on training deficiencies that impact on the MTF's ability to perform its first receiver mission.

The CBRNE Science Branch was assigned the task to develop an Army Training and Evaluation Plan containing individual, collective, and leader tasks for fixed military MTFs to support installation protection missions and plans for CBRNE and all other hazards. The training documents traditionally have a unit/ activity doctrinal manual to provide operating principles and techniques that allow the training developer to analyze and enumerate collective tasks for the entity. In this case, there was no baseline publication for fixed installation MTFs, thus, the team relied on an extensive literature review to help develop the tasks.

The unit, leader, and individual training syllabi support the accomplishment of both Homeland Security missions and traditional full spectrum military operations. Therefore, current doctrinal manuals, Army Training and Evaluation Plan–Mission Training Plans, and federal government response guidelines offer a wealth of information on training tasks that can be adapted for installation MTFs. According to the *Army Training and Doctrine Command Regulation 350-70*,[2] a revision of tasks rather than a full-scale developmental effort is preferred for training similar missions in a different environment or setting. By identifying tasks from current documentation, the team can build a basic outline from which to further analyze and refine required CBRNE tasks for a fixed MTF.

Once candidate tasks have been defined, a mission/job analysis must still be conducted to identify critical collective tasks. This is a key step, since the collective tasks performed to accomplish a unit or MTF mission will drive the development or revision of individual and leader tasks that directly support the mission. Mission analysis identifies unit organizational and functional structure before development of unit training products.

Armed with baseline collective, leader, and individual tasks, members of the team and a government representative will conduct site visits to MTFs. This is required to receive input from the MTF commander and staff and to analyze candidate tasks within the context of existing installation plans and standard operating procedures.

As a result of site visits and continuing analysis and development, a list of proposed collective, leader, and individual tasks are presented for review. An example of proposed tasks in support of CBRNE events are:

- Perform public health emergency officer functions
- Conduct termination planning
- Conduct interagency coordination
- Review and update CBRNE incident response plan

A task validation board or some other proponent mechanism will then be convened for further review and selection to approve the proposed tasks. Once that approval is received, the training developers will enter the tasks into the Automated Systems Approach to Training.

The trainers/evaluators will develop and present a training evaluation plan based on the approved collective, leader, and individual tasks. Training evaluation is the process used to identify task performance and deficiencies in unit and individual training, and to obtain recommendations for improvement of training, or the products that support training. There is no specific procedure prescribed for Army Training and Doctrine Command proponents in the development or conduct of unit training evaluation. The procedures selected are dependent upon a variety of factors, including, in this case, the MTF real-world workload, whether the unit can be visited by external evaluators, whether actual training execution can be observed, and how many unit personnel are available to participate in an exercise or other evaluation vehicle. By its very nature, CBRNE response exercises in a Homeland Security scenario require enormous amounts of coordination and resources from local, state, and federal agencies and role players to provide

the proper test conditions. Therefore, standard Army and AMEDD evaluation regimens may yield to the Department of Homeland Security and/or state emergency management evaluation schedules and requirements. Individual and leader task evaluations can be done in the schoolhouse or at the MTFs by use of student performance measurement and testing, including practical exercise, and therefore lend themselves to a regular assessment schedule without the need for a large commitment of resources. The evaluators will take these factors and AMEDD guidance into account in development of the evaluation plan.

Training and evaluation exercises for a fixed MTF are inherently difficult for the commander for a variety of reasons. Most notably, the hospital or clinic must perform real-world missions, resulting in severe time and resource constraints for training missions, which impact personnel availability issues. Despite the need to perform day-to-day operations, the facility must train and undergo periodic evaluations in accordance with directives, not only from higher command, but from civilian agencies such as the Joint Commission on Accreditation of Healthcare Organizations and the Department of Homeland Security. The strategy selected by the commander for training MTF departments must include various methods of training individuals, designated staff, leaders, and the department and facility staffs as a whole.

ACKNOWLEDGEMENT

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The Army Preventive Medicine Specialist in the Medical Education and Training Campus Era

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OVERVIEW

On 15 September 2005, President Bush endorsed the Department of Defense (DoD) Base Closure and Realignment Commission's (BRAC) report and forwarded it to Congress. The congress had 45 legislative days, until November 9, 2005, to accept or reject the report in its entirety. However, it was not authorized to make any changes to the final report.[1] Since the congress took no action before the deadline, the BRAC recommendations became law. By statute, DoD had until September 15, 2007, to initiate closing and realigning the installations specified in the report. Additionally, the process must be completed by September 15, 2011.[2]

Included in the BRAC recommendations was Commission Recommendation 172, San Antonio Regional Medical Center, Texas.[3] It is within this recommendation that the concept of the Medical Education and Training Campus (originally submitted under BRAC as the Medical Enlisted Training Center) was established. The recommendation specifically was to relocate "…all (except Aerospace Medicine) medical basic and specialty enlisted training at Fort Sam Houston, Texas, with the potential of transitioning to a joint training effort."[4] In response to the requirement for the Medical Education and Training Campus, the Army Medical Department Center and School (AMEDDC&S) directed its subordinate teaching departments to coordinate with the Interservice Training Review Organization (ITRO). The ITRO then conducted meetings among the services to determine if courses would collocate or integrate. The specified construct was:

- Quick Look Group
- Detailed Analysis Group
- Resources Required Analysis

While this process is uniform for all, the remainder of this article will focus on its application to Preventive Medicine.

QUICK LOOK GROUP

The Preventive Medicine Quick Look Group, composed of the Army 68S10* Program Manager, Class Advisor, and Instructional Systems Specialist; and the Navy Program Manager, Service Lead, and Instructional Systems Specialist; along with various ITRO staff, met from September 12-14, 2006. This 3-day initial study revealed sufficient commonality existing between the US Army Preventive Medicine Specialist Course† and the US Navy Preventive Medicine Technician Course‡ to propose consolidating a majority of the training and recommend continuing the ITRO process. The members of this Quick Look Group agreed to future meetings to develop a consolidated curriculum and identify computer based training opportunities. It was agreed that membership of these studies should include the current participants. The Quick Look Group made the following specific recommendations:

- Ensure a joint services curriculum and required support facilities will be in compliance with current certification/accreditation requirements.
- Coordinate proposed facilities plans with service subject matter experts.
- Due to shipboard and Fleet Marine Force training requirements, Navy students must have phase II, Navy specific sites (ie, shipboard training).
- Phase II sites will require dedicated instructor staff.[5(p6)]

*Army Military Occupational Specialty 68S10, Preventive Medicine Specialist
†Army Training Course 322-68S10
‡Navy Training Course HM 8432

Since the US Air Force enlisted preventive medicine personnel are considered part of the aerospace medicine community, their training will relocate from Brooks City Base, San Antonio, TX, to Wright-Patterson Air Force Base, Dayton, OH. Consequently, the Air Force is not part of the BRAC-driven preventive medicine training review and reorganization.

DETAILED ANALYSIS GROUP

The meeting of the Preventive Medicine Detailed Analysis Group was held March 6-8, 2007. The military training personnel who were previously part of the Quick Look Group conducted an in-depth analysis of the 2 programs of instruction (POI) conducted in the training of service specific preventive medicine personnel.

The Army trains Preventive Medicine Specialists (Military Occupational Specialty 68S10) for 15 weeks (75 academic days) at the AMEDDC&S, Fort Sam Houston, Texas. For planning factors, the Army training requirement for Fiscal Year (FY) 2010 is 209 students. The basic course* consists of 532 hours of didactic/laboratory/practical training, and 110 hours of field training exercises and situational training exercises—a total of 642 academic hours. At the time of review by the Detailed Analysis Group, there were 7 class iterations per year, with a maximum class population of 32 students, minimum of 12 students, and an average of 21. The enrollment pay grade for Active Army Soldiers is E4 or below, E6 or below for members of the Reserve Component. As a part of the POI, students must pass specified areas of the DoD Pest Management Certification exam. Additionally, they are offered the opportunity to take the ServSafe® certification examination.†

The Navy trains Preventive Medicine Technicians (PMT) for 26 weeks (130 academic days) at the Naval School of Health Sciences, San Diego, California. The Navy training requirement for FY 2010 is 160 students. The Navy uses multiple clinical and field training sites, including ships, fixed facilities, and local civilian facilities. The PMT basic course consists of 844 hours of didactic/laboratory/practical training (including a 160-hour course: Medical Entomology and Pest Management Technology for PMTs), and 64 hours of other required training and activities. The training totals 1,040 hours. At the time of review by the Detailed Analysis Group, there were 4 class iterations per year, with a maximum class population of 40 students, minimum of 20 students, and an average of 40. The enrollment pay grade for active duty Navy is E3 through E7. This course is open to Navy Reserve and Coast Guard personnel. As a part of the POI, students are required to pass specified pest management categories of the DoD Pest Management Certification exam. Students may take the Certified Environmental Health Technician exam from the National Environmental Health Association.[5(p6)]

During the Detailed Analysis Group working sessions, the Army and Navy representatives presented several concerns for further examination:

Army

- AMEDDC&S will be able to continue to invite international students to attend preventive medicine training.
- Ensure that food service sanitation remains in the curriculum to enable Army students to successfully pass the ServSafe Exam.[5(p5)]

Navy

- Scope of practice – a concern because Navy PMTs operate clinically, unlike Army preventive medicine personnel.
- Course content – considered an opportunity since Joint Occupational and Environmental Health Surveillance is largely undocumented in the Navy POI[5(p5)] (current requirements driven by a DoD Directive,[6] a DoD Instruction,[7] and a memorandum from the Chairman of the Joint Chiefs of Staff[8]).
- Requirement for a Phase II clinical site – since there are no shipboard environment training facilities at Fort Sam Houston, teaching shipboard practices would be problematic.
- Accreditation/certifications – maintaining accreditation/certifications was viewed as a critical requirement, which is consistent with other programs relocating and integrating into the Medical Education and Training Campus concept.

*Army Training Course 322-68S10

†The ServSafe Food Safety Certification is a risk management program of the National Restaurant Association Educational Foundation. ServSafe is the most widely accepted food safety program among local, state, and federal health departments. Information available at http://www.nraef.org.

As a result of the work of the Preventive Medicine Detailed Analysis Group, a recommendation for the core consolidation of approximately 449 hours of instruction was submitted. The resultant total Army course length will be 642 hours, the Navy course length will be 1,120 hours. Within each syllabus, 449 hours of instruction will be presented in a joint format.[5(p7)]

RESOURCE REQUIREMENTS ANALYSIS

The Preventive Medicine Resources Required Analysis was conducted at the AMEDDC&S, August 14-16, 2007. The following were the areas of focus during the sessions:

Manpower analysts identified instructor, average daily student load, and student man-year requirements. The representatives reviewed the course model data developed during the Detailed Analysis Group. The group consensus was a consolidated lecture ratio of 2:56 (later amended to 2:61). The discussion focused on the requirement to divide students into groups with a ratio of 1 instructor for every 6 students during the majority of the consolidated laboratory exercises. Service instructors expressed concerns that instructor/ student ratios should be preserved. This concern was due to the fact that proper instructor/student ratios were not initially being maintained during overlapping iterations (overlapping iterations drive requirements to 21 instructors, without regard to service). The manpower cost model initially authorized 17 instructors (8 Navy, 9 Army). After further analysis, 21 instructors (10 Navy, 11 Army) were authorized, thereby resolving concerns about instructor/student ratios. The initial class size was 56 students (36 Army, 20 Navy) with 6 projected class iterations.[9] These numbers were revised at the design charrette* for the Medical Education and Training Campus buildings 3 and 4, raising class size to 61 students (35Army, 26 Navy).

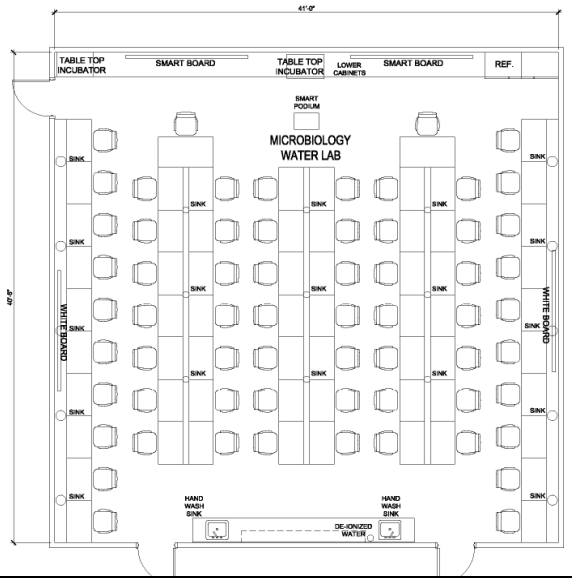

Figure 1. Planned preventive medicine microbiology/ water analysis laboratory classroom (61 students, 1,661 sq ft) for the consolidated and integrated enlisted preventive medicine instructional facility at Fort Sam Houston, Texas.

Facilities analysts did an in-depth review to identify all requirements needed to support training. The analysts used FY 2010 year of execution data and service student numbers for all studies. The analysts, in conjunction with service subject matter experts, determined the consolidated and integrated enlisted preventive medicine instructional facility would have 4 laboratories: microbiology/water analysis (Figure 1), industrial hygiene (Figure 2), medical entomology, which would have an associated small multifunction lab primarily used by the Navy for clinical aspects of public health (Figure 3). In addition, 4 student lecture classrooms were designed: one for 61 students in a joint lecture environment, one for 36 students for Army specific lecture, and 2 classrooms, each seating 26 students for Navy specific lectures.

Resources Required Analysis attendees met with the Medical Education and Training Campus/Transition Integration Office (METC/TIO) staff to determine equipment requirements, manpower overhead, and the concept of operations.

The METC/TIO staff also discussed academic concerns regarding curriculum development, clinical sites, and accreditation and certification issues.[9(p3)]

The Navy representatives expressed several concerns relative to academics and associated accreditation and certification. For example, the Program Director must be a credentialed (grade O5) Environmental Health Officer or Army equivalent Environmental Science

*A final, intensive effort to finish a project before a dead-line. Source: *Random House Unabridged Dictionary.* New York, NY: Random House, Inc; 2006.

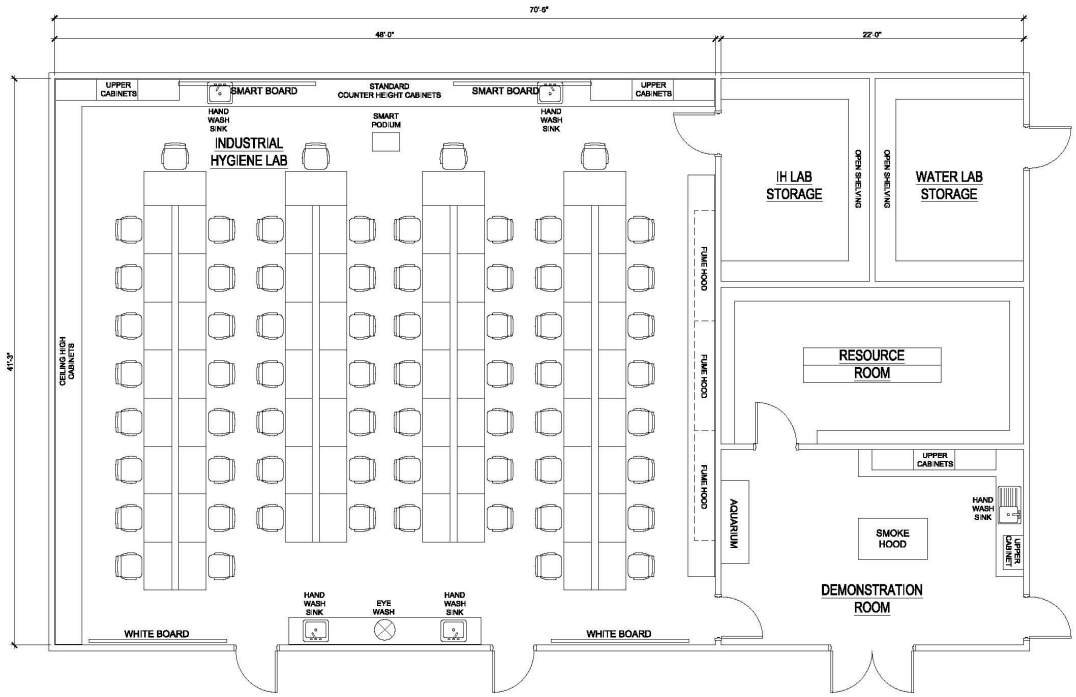

Figure 2. Planned preventive medicine industrial hygiene laboratory classroom (2,905 sq ft) for the consolidated and integrated enlisted preventive medicine instructional facility at Fort Sam Houston, Texas.

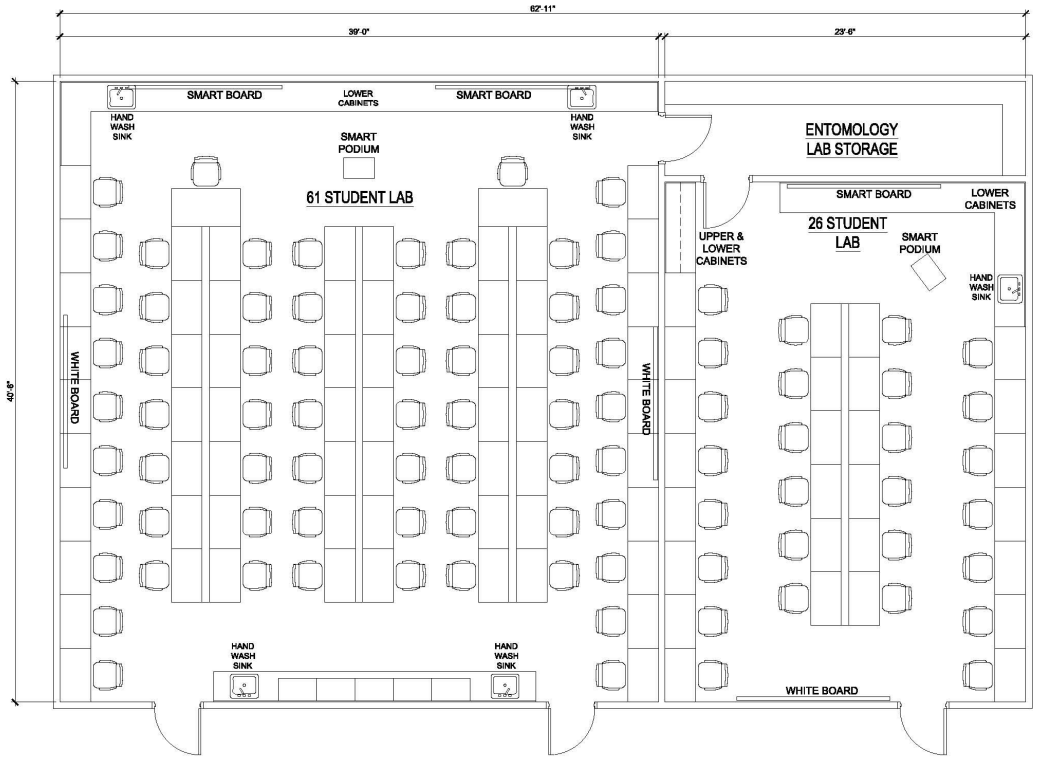

Figure 3. Planned preventive medicine medical entomology laboratory classroom (2,548 sq ft) for the consolidated and integrated enlisted preventive medicine instructional facility at Fort Sam Houston, Texas.

and Engineering Officer (ESEO) to meet requirements which allow Navy students to sit for certification exams. As previously discussed, Navy PMTs are currently eligible for the National Environmental Health Association professional certification* as a Certified Environmental Health Technician (CEHT). The Navy PMTs take the CEHT examination at the end of the entire curriculum (including clinical training) prior to transfer to their next duty station. Navy PMTs are eligible for the examination based on the current Navy curriculum which allows the student to earn 48 to 60 semester hours of credit towards the Bachelor of Science (Health Sciences) degree completion program at selected colleges and universities.[10] Since the Army requires credential certification of all field grade ESEOs,[11] the Navy agreed to the rotation of the directorship of this program.

DESIGN CHARRETTE

After the Resources Required Analysis, the METC leadership team held a series of design charrettes, which included AMEDDC&S preventive medicine representatives, to address each of the Medical Instructional Facilities (MIF) (preventive medicine is assigned to MIF-4). It is within this process that detailed requirements for laboratories, classrooms, white boards, smart podiums, etc, were documented. The results of this effort yielded a formal request for proposal, which, at the time this article was written, had not been released.

CONCLUSION

The US Army has invested heavily in the future of preventive medicine. They have driven detailed analyses of time, programs of instruction, and equipment and facilities required to produce the Soldiers of tomorrow. Make no mistake, the future of the Army Preventive Medicine Specialist is bright. From Initial Entry Training/Advanced Individual Training, our Soldiers will have the benefit of working and learning in a joint services environment. While the initiative for a unified medical command was not adopted because of the significant differences in organization, responsibilities, and operations of US Air Force preventive medicine assets relative to the Army and Navy, the Services have been directed by the Deputy Secretary of Defense into a "new governance plan."[12] This plan focuses on medical research, medical education and training, health care delivery in major markets, and shared support services. While this does not include battlefield health care, the primary and most crucial reason for considering a unified medical command, the Army Preventive Medicine Specialist and Navy Preventive Medicine Technician will reap the benefits of BRAC 2005 Recommendation 172.[3] This is because both Army and Navy preventive medicine personnel serve in infantry units—the Army brigade combat team and the Navy in the Marine Corps infantry battalion. Currently, in Iraq and Afghanistan there are countless examples of Army and Navy preventive medicine units working both interoperably and interchangeably, furthering DoD's Force Health Protection requirements. By starting this orientation of our Soldiers at the earliest point in their Army career, the Army and Navy will only improve this requirement.

*Information available at: http://www.neha.org/credential/

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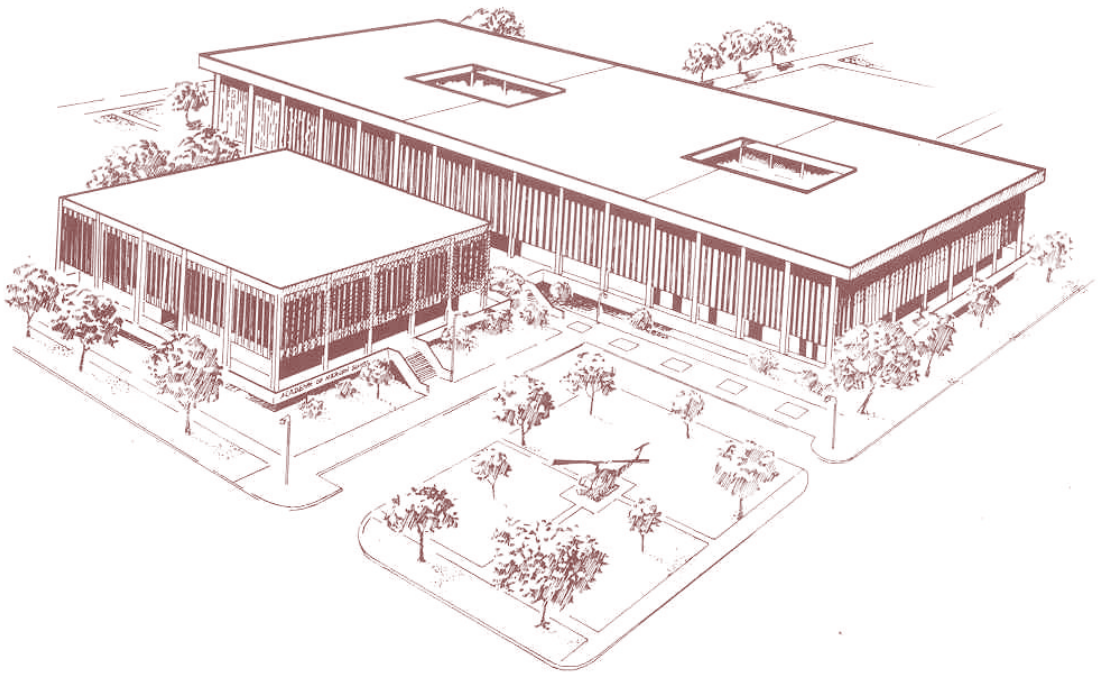

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Malaria Risk Assessment for the Republic of Korea Based on Models of Mosquito Distribution

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ABSTRACT

Data on climate, environment, and adult and larval mosquito collection sites throughout the Republic of Korea (ROK) were used to model the potential distribution of the 8 anopheline species known to occur there. These models were overlaid on predicted areas of malaria suitability to better define the distribution of malaria risk in the ROK. The concept of the "mal-area"— an area of co-occurrence of humans, parasites and vectors, where malaria transmission is possible—is explained. Quantification of the mal-area in the vicinity of 5 military installations in the north of the country suggested that they had very different malaria risks, depending on what the vector species were, and the method of calculation. An online mal-area calculator for malaria risk assessment (currently under development) is discussed.

INTRODUCTION

Arthropod-borne pathogens that cause diseases, such as malaria, yellow fever, and dengue, are major health threats to the military. For example, losses to malaria and other preventable diseases among Allied forces operating in the China-Burma-India theater during World War II far exceeded the number of casualties inflicted by enemy action.[1] Malaria was second only to combat injury as the reason for hospitalization among American troops in Vietnam, and the number one reason for troops deployed to Somalia.[2] A significant proportion of Joint Task Force personnel inserted into Liberia in August 2003 (80 out of 290 who had been ashore) experienced symptoms of malaria.[3] Infected troops returning to the United States increase the rate of imported malaria.[4]

Anopheles mosquito species are solely responsible for global malaria cases. Over 450 species of *Anopheles* are known, but only a fraction are malaria vectors. More precise information on the actual and potential geographic distribution of the species responsible for malaria could assist a host of health-related actions, including predeployment counselling for prophylaxis; the choice of health messages during deployment; decisions as to the locations of refugee camps, hospitals, and bases; postdeployment evaluation of health risk exposures; selection of the type and extent of vector control; the choice of vector identification tools; identification of the likely vector for a region; and management or quarantine of invasive vector and parasite species.

Recently, computer programs have become available that combine climate information with data on where organisms have been collected to produce maps of the potential distribution of these organisms.[5,6] A variety of mosquito species have been modeled in this way.[7,8] The output from these models, usually the suitability for occurrence of a particular species, can be extended to a resolution of one km^2 or less.

The zone where humans, parasites and vectors co-occur constitutes a geographic area of malaria risk that we dub the "mal-area" (see Figure 1). The mal-area can be regarded as the ecological niche or potential spatial extent of this disease.[9] A subset of the ecological niche is the mal-area of current transmission, which expands and contracts according to the level of mosquito survival and abundance, human-vector contact, and case detection and

treatment, among a myriad of other factors. Because the *Plasmodium* parasite is normally dependent on a human or mosquito host, the mal-area should approximate the spatial extent of the parasite. The phenomenon of "anophelism without malaria" describes the area where vectors and humans, but not parasites, co-occur, eg, many populated parts of the United States have malaria vectors but the disease was eradicated there.

Until recently, detailed intelligence on the distribution of vectors was not available for malaria risk models. The Malaria Atlas Project[10] (MAP) models the limits of actual malaria transmission using information on international travel-health guidelines and estimates of vector occurrence, from altitude and degree of urbanization data.[11]

Fine-tuning such maps of global malaria suitability by incorporating detailed mosquito species distribution models could provide a clearer picture of areas of heightened malaria risk. The resulting mal-area extent could be used as a simple index to compare malaria risk between locations of interest (Figure 1). Specifically, mal-area mapping could improve force health protection in areas of operation such as the Republic of Korea (ROK) that have a history of malaria transmission.

Prior to the 1950s, *Plasmodium vivax* malaria was endemic and widespread in the ROK,[12] suggesting that the potential mal-area is extensive in that country. Malaria was eradicated in the 1970s but reemerged in 1993 and reached a peak of 4142 cases in 2000 before falling to 774 cases in 2004.[13] Most malaria cases appear to have been contracted near the Demilitarized Zone (DMZ) that separates North and South Korea.[13] This is reflected in the northerly location of the area of current malaria suitability, as determined by the MAP models (see Figure 2). The anopheline fauna of South Korea (ie, the ROK) is relatively well resolved taxonomically,[14-16] and ongoing mosquito surveillance makes this country an ideal location to test the mal-area approach to assessing malaria risk. The anopheline fauna of the ROK includes 8 species:

Anopheles sinensis sensu stricto (s.s.) Wiedemann

An. pullus M. Yamada (=*An. yatsushiroensis*)

An. lesteri Baisas & Hu (=*An. anthropophagus*)

An. sineroides S. Yamada

An. kleini Rueda

An. belenrae Rueda

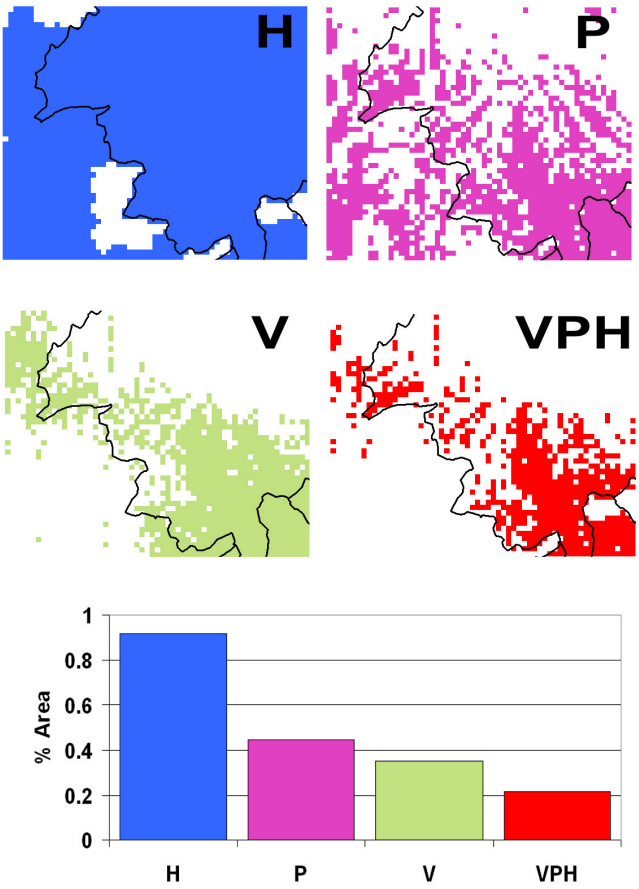

Figure 1. Illustration of the concept of the mal-area as it applies to malaria risk assessment in geographic space. Presence/absence of humans (H), areas of suitability for *Plasmodium* species (P), and predicted distribution of malaria vectors (V) are shown, as well as the mal-area (VPH); the area of overlap where malaria transmission is possible. Histogram shows the percentage of the sampled area that these parameters cover. The value for VPH could be used as a simplified index of malaria risk to compare different areas.

An. lindesayi japonicus S. Yamada

An. koreicus S. Yamada & Watanabe

These species are not all identifiable based on morphology, but a polymerase chain reaction (PCR) technique has been developed for species identification.[15] Historically, *An. sinensis* was considered the primary vector. However, the discovery of additional species and results from field and laboratory parasite studies have combined to point to *An. kleini*, *An. pullus*, and *An. sinensis* as the likely vectors around the DMZ.[13] Logically, since further mosquito and parasite sampling is required, all species could be regarded as potential vectors.

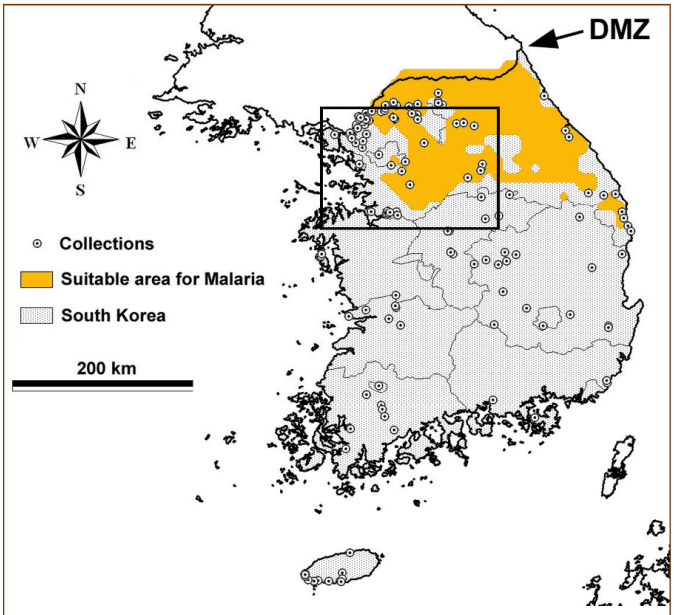

Figure 2. Locations of mosquito collection points in the ROK used in species distribution modelling. Also depicted is the extent of the area predicted active for malaria. (Data derived from the Malaria Atlas Project.[10] Data from the boxed area was used for mal-area calculations.

We used climate and adult and larval mosquito collection data from sites throughout the ROK to model the distribution of all 8 anopheline species. To better understand the distribution of malaria risk in the ROK, especially around military installations in the north of the country, the resulting models of potential species distributions were compared with areas of malaria suitability. An online mal-area calculator for malaria risk assessment that is under development is discussed later in this article.

MATERIALS AND METHODS

Adult mosquito surveillance was conducted at selected US military installations using New Jersey light traps (John W. Hock Co, Gainesville, FL) and Mosquito Magnets® (Woodstream Corporation, Lititz, PA) (Figure 3), and larval collections were made throughout the ROK. Adults and larvae were identified to species by comparison of DNA products produced by PCR.[15]

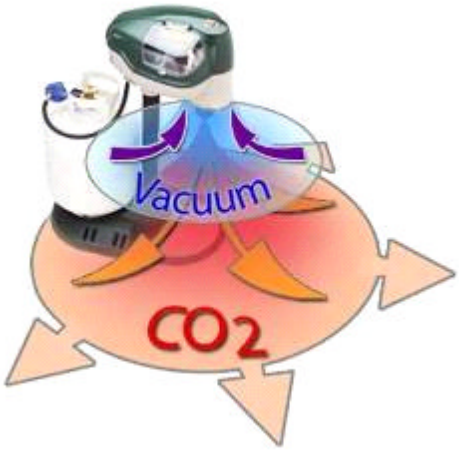

Figure 3. The Mosquito Magnet uses propane to produce CO_2 and heat to attract insect vectors which are caught in the vacuum and deposited in the collection bag.

We used the Genetic Algorithm for Rule-set Prediction (GARP)[5,17] and a maximum entropy approach, known as Maxent,[6,18] for distribution modelling. GARP uses an iterative process of rule selection, evaluation, testing, and incorporation or rejection. The genetic algorithm in GARP allows the rules to "evolve" to maximize predictive accuracy. A rule is selected and is applied to half the points (training data) and models assessed with the other half of the points (testing data). The change in predictivity between iterations is used to evaluate whether a particular rule should be incorporated into the model. Maxent is based on the idea that the best explanation for unknown phenomena will maximize the entropy of the probability distribution, subject to the constraint of the environmental conditions where species have been detected. Output was predicted probability of presence. The methodology and results of this modelling will be reported in greater detail in a forthcoming paper.

We obtained

- altitude and a selection of climate grid layers for 1980 through 1990 from Worldclim,[19]
- five layers summarizing aspects of topography and landform (topographic index, slope, aspect, flow direction, and flow accumulation) from the US Geological Survey's HYDRO-1K Elevation Derivative Database,[20]
- data layers summarizing the "greenness index"—termed the Normalized Difference Vegetation Index[21]—from the Advanced Very High Resolution Radiometer satellite data presenting percentage tree cover for 1992-1993,
- thirteen classes of land-use/ land-cover from the Global Land Cover Facility,[22]
- soil taxonomy suborders of the world from the US Department of Agriculture National Soils Conservation Service,[23] and
- data on areas equipped for irrigation from the Aquastat site of the Food and Agriculture Organization of the United Nations.[24]

In all, 79 one-km^2 environmental data layers were available, which we reduced to 15 by principal components analysis (PCA) in Minitab 15.1.1.0 (Minitab Inc, State College PA) prior to mosquito distribution modelling. The 15 PC layers explained more than 95% of the overall variation in the 79 environmental parameters. We imported data into ArcView 3.3 (ESRI, Redlands, CA) for image analysis.

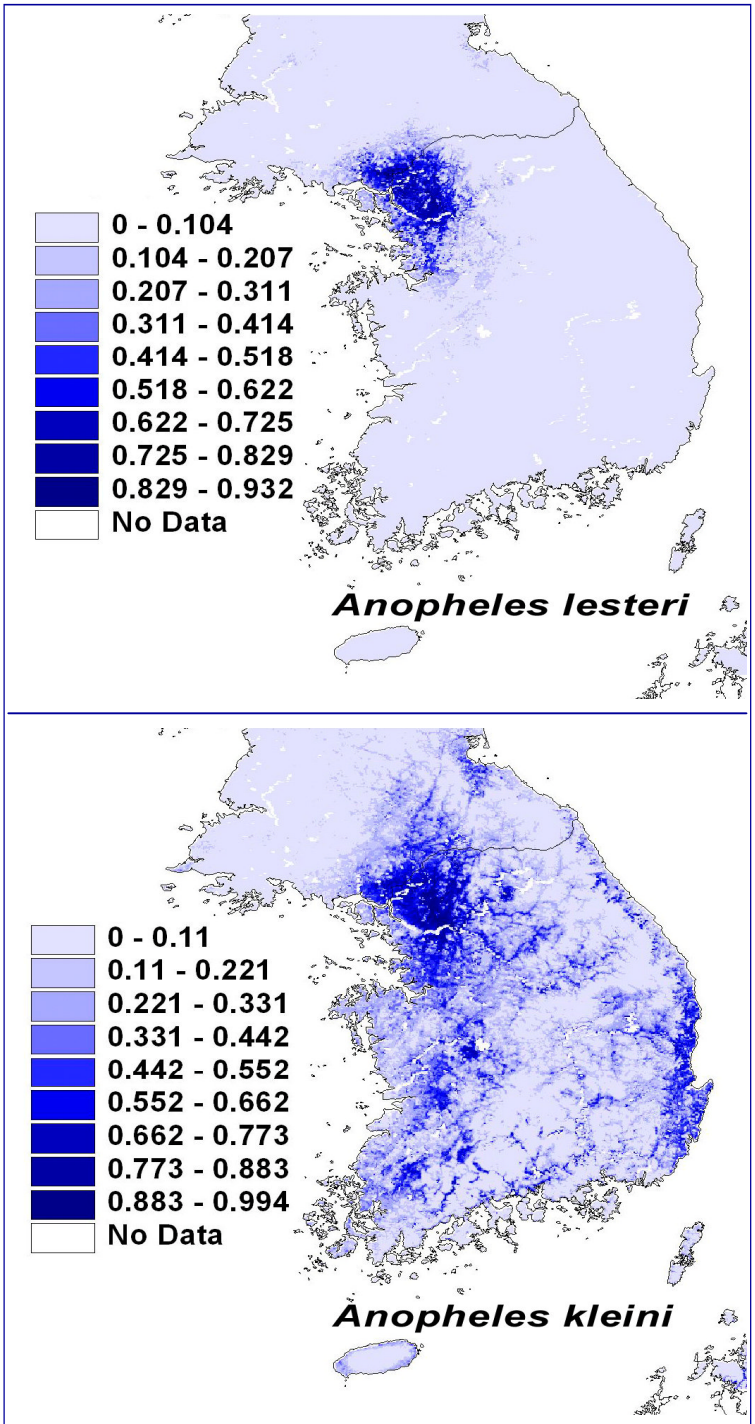

Figure 4. Examples of Maxent models of the potential distribution for 2 anopheline species in the ROK, based on mosquito collection data and environmental data layers. Darker shading indicates greater predicted suitability of that area for the occurrence of that species.

The current spatial limits of *P. vivax* in the ROK were taken from the MAP website[10] and resampled for one-km^2 resolution to match that of the mosquito distribution models (see Figure 2). We assumed that human population density throughout the areas of interest was sufficient for malaria transmission. We applied a 10-km radius buffer around 5 selected US military installations in the northeast of the ROK. Using ArcView 3.3, we conducted map queries for 3 scenarios for possible areas of coincidence of vectors and malaria within the buffers, where false = 0 and true = 1. We also conducted a map calculation for a fourth scenario where no coincidence of vectors and malaria = 0, one vector species coinciding with malaria = 1, two species coinciding = 2, and three species coinciding with malaria = 3. In scenario 1, only one species, *An. sinensis*, is considered a vector, as had been assumed by workers in the past. Scenario 2 assumes that any of the 8 anopheline species occurring in the ROK can transmit malaria if they co-occur with the spatial limits of parasites. This is the most conservative scenario. Scenario 3 assumes *An. kleini*, *An. pullus*, and *An. sinensis* are vectors, as has been suggested in the literature.[13] In this scenario the co-occurrence of any or all of these species with the malaria suitable area is scored as true (= 1) for the purposes of the mal-area calculation. Scenario 4 assumes *An. kleini*, *An. pullus*, and *An. sinensis* are vectors, but that the risk increases if more than one species co-occurs with the malaria suitable area. These species were equally weighted, as definitive information on their relative vectorial importance is lacking. The total number of one-km^2 pixels scored true for the first 3 scenarios, and the sum of values for these pixels for the fourth scenario were calculated for the buffered areas surrounding the 5 installations.

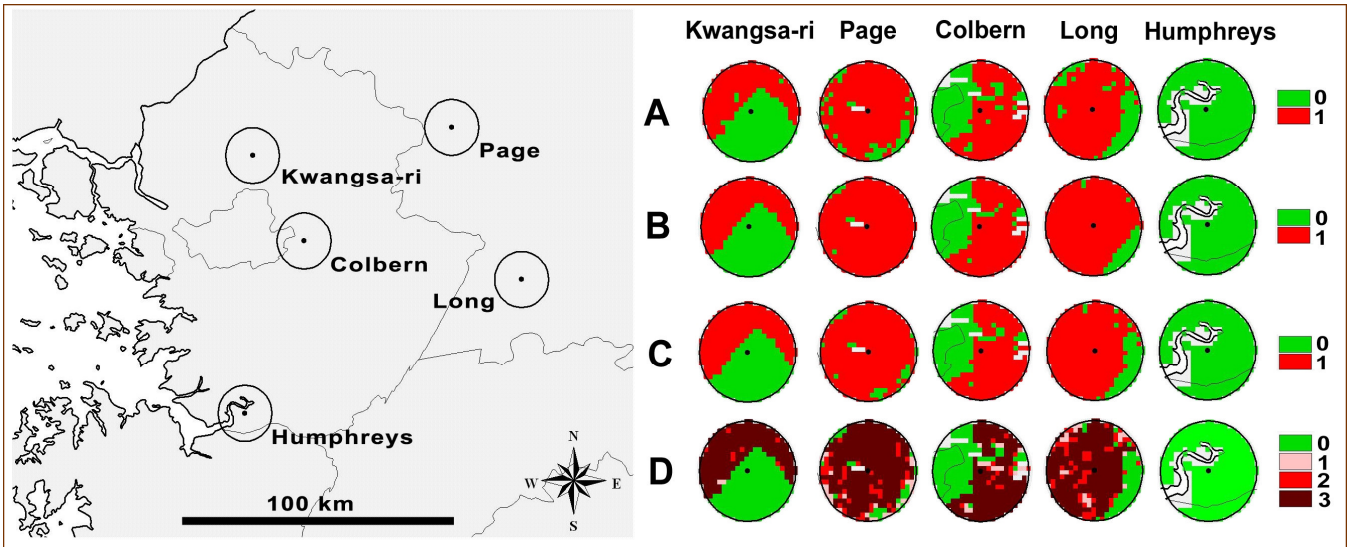

Figure 5. Four scenarios of the extent of the mal-area for malaria within 10 km of 5 US military installations in the ROK (one-km^2 pixel resolution), based on vector distribution models and the areas predicted suitable for malaria, from the Malaria Atlas Project.[10] Darker areas indicate greater risk of malaria.

Legend:

A. *Anopheles sinensis* is the only vector.
B. Any of the 8 *Anopheles* species known from the ROK are present.
C. Any of 3 species (*An. kleini*, *An. sinensis* and *An. pullus*) is present.

RESULTS

Mosquitoes were identified to species from a total of 174 collection locations in the ROK from collections from 1998 through 2006 (see Figure 2). Some of these data were reported previously.[25] Distribution models revealed that *An. sinensis*, *An. kleini*, *An. pullus*, and *An. belenrae* were predicted to occur widely, whereas *An. lesteri* is predicted to occur only in northwest areas of the ROK (Figure 4). Examples of output from Maxent models for *An. kleini* and *An. lesteri* are presented in Figure 4. Collection data and distribution maps will be available from the MosquitoMap website* and in a future publication. All species are predicted to occur in the north of the ROK where malaria has been most common since it first reappeared in 1993.

Mal-area calculations for the 4 scenarios are shown in Figure 5. In all scenarios, Camp Humphreys has no malaria transmission risk due to it falling outside the predicted spatial limits of malaria as given on the MAP website.[10] Comparison of the mal-area scores (Figure 6) reveals that Camp Humphreys and Kwangsa-ri have the lowest values. The scores for scenario 4 are higher than for the other scenarios, reflecting the cumulative effect of vector species' occurrences on malaria risk. In these examples, the rank of the malaria risk of the 5 installations does not change markedly with the different scenarios, except that Colbern has a higher score for the *An. sinensis*-only scenario.

DISCUSSION

Arthropod-borne infectious diseases are a major health threat to our combat troops. We cannot afford to ignore this health threat nor repeat the mistakes of previous conflicts where many Soldiers were debilitated or killed by preventable infectious diseases. Knowledge of the identity and occurrence of the major vectors is a prime requirement to determine the threat posed by vector-borne diseases. Predicting where the vectors are likely to be found could be a valuable addition to health risk assessment and disease control strategies.

As standardized and accessible techniques for modelling the distribution of disease vectors are recent developments, the approach given here is new. Application of models of vector distribution to disease risk assessment is a logical next step. We have shown that a simple index of the area where disease

*http://www.mosquitomap.org

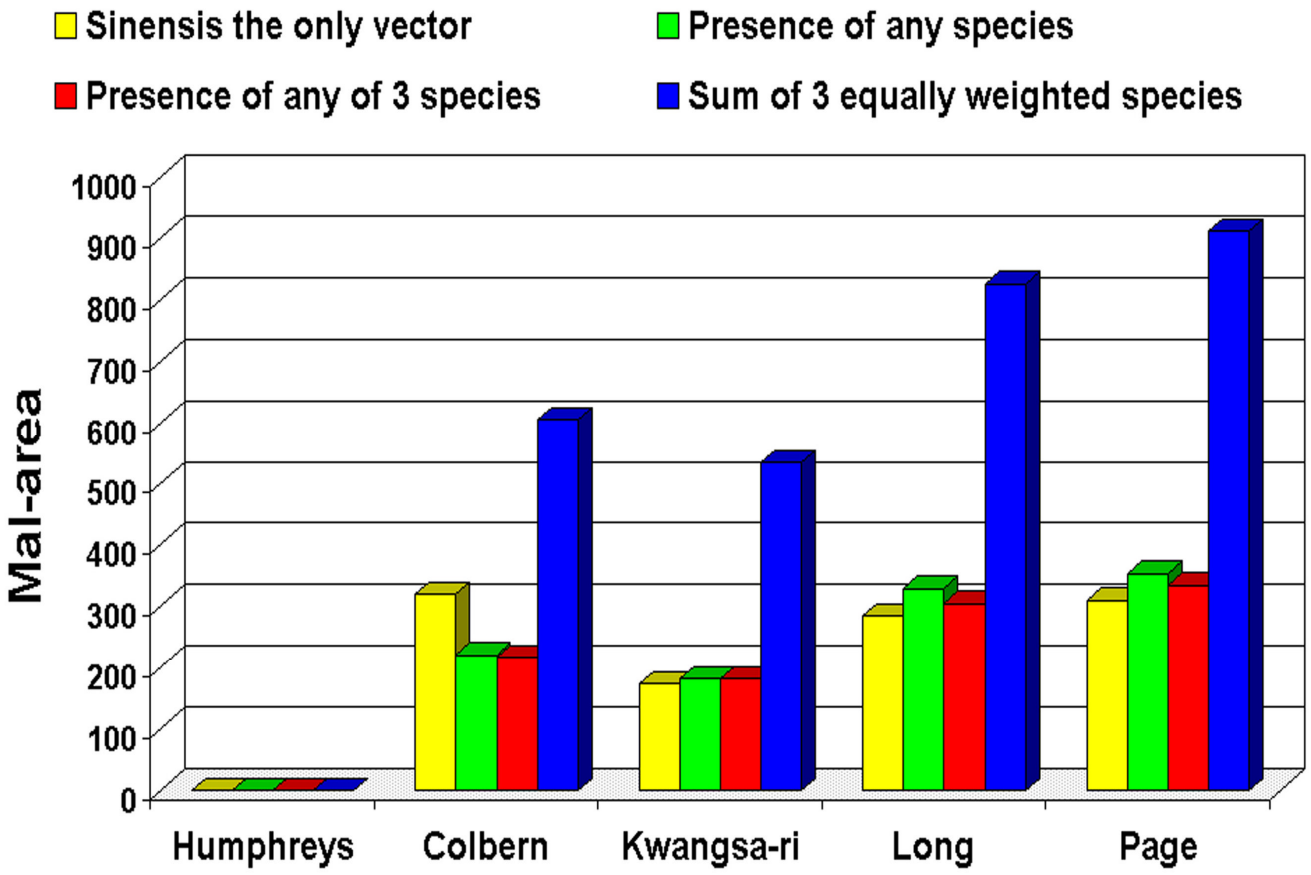

Figure 6. Mal-area calculations in number of one-km^2 pixels for malaria within 10 km of 5 US military installations in the ROK, based on vector distribution models and the areas predicted suitable for malaria, from the Malaria Atlas Project.

transmission is possible, the mal-area, can be used to assess disease risk for a 10 km radius buffer around US military installations in the ROK. Although any size area can be considered, a 10-km buffer is appropriate to calculate the health risk arising from the local environment, or the amount of vector control needed within a barrier zone around these points.

We have shown that the method of calculating the mal-area is an important variable. Identification of the vector species, and the weight attached to these species in terms of vectorial importance is also critical. However, the accuracy, scale, and precision of models of vector and parasite distribution is of fundamental importance. It should be noted that little information is available for malaria in North Korea[11] and so the malarious area may extend further north than shown here. The World Health Organization reported that a malaria epidemic occurred in North Korea shortly after the first case of malaria reemerged along the DMZ in 1993, suggesting a parallel outbreak occurred in both countries.[26] The mal-area calculations shown here do not yet take into account seasonality, use of insecticide bed nets, human movement, socio-economic level, or many other variables that modify the prevalence and incidence of malaria. In addition, vector distribution models predict general habitat suitability, but factors not included in these models include historical, physical, climatological, and biotic constraints that may play a role in limiting potential distribution. Evaluating and improving vector model accuracy is an ongoing task, but better models can be easily incorporated as they become available.

Despite the simplified assumptions of the mal-area method of risk assessment shown here, the approach is potentially very quick and can be used for any area of interest in the world, even where medical intelligence is sketchy. One can see the location of the mal-area within the area of interest, or the mal-area can be

reduced to a single figure to compare risk between areas. In the absence of other intelligence, the mal-area approach has potential as a first approximation of risk. Alternatively, vector and mal-area maps can be used as base layers in more complex epidemiological GIS disease risk models. A generic mal-area tool could conceivably be used to measure any risk factor, including other vector-borne diseases, where spatial models of the risk components are available. Such a tool would have great value for medical intelligence estimates, particularly when forces are deployed to hostile locations for the first time.

We are constructing high resolution maps of potential geographical distribution of a selection of mosquito vectors of disease which will soon be available via the MosquitoMap website, an online clearinghouse for georeferenced mosquito collection records, and species distribution models derived from those records. MosquitoMap uses ArcGIS Server 9.2 to enable the query and mapping of georeferenced mosquito collection records as points or country-level aggregations. Data come from records held by museums, scientific literature, and private collections. Currently there are 65,000 records, mainly for Australasia and the Neotropics.

An application within MosquitoMap, the mal-area calculator, is designed to provide a fast, easy, and intuitive interface for rapidly assessing relative malaria risk. The intention is for the user to define a location or area anywhere on the face of the earth and the calculator combines models of disease distribution with predicted distribution of major disease vectors. Based on the location or area defined, an HTML and/ or PDF chart will be rendered that graphs statistics for grid layers of various combinations of the VPH variables. These statistics will consist of the percentage of cells that contain a certain value for the user defined area. MosquitoMap and the mal-area calculator rely on distribution models for all vector species, but these are currently lacking. However, these applications provide a framework to host and analyze future vector and disease models as they become available.

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The US Air Force Aerial Spray Unit: A History of Large Area Disease Vector Control Operations, WWII Through Katrina

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ABSTRACT

The US Air Force has had a long history of aerial applications of pesticides to fulfill a variety of missions, the most important being the protection of troops through the minimization of arthropod vectors capable of disease transmission. Beginning in World War II, aerial application of pesticides by the military has effectively controlled vector and nuisance pest populations in a variety of environments. Currently, the military aerial spray capability resides in the US Air Force Reserve (USAFR), which operates and maintains C-130 airplanes capable of a variety of missions, including ultra low volume applications for vector and nuisance pests, as well as higher volume aerial applications of herbicides and oil-spill dispersants. The USAFR aerial spray assets are the only such fixed-wing aerial spray assets within the Department of Defense. In addition to troop protection, the USAFR Aerial Spray Unit has participated in a number of humanitarian/relief missions, most recently in the response to the 2005 Hurricanes Katrina and Rita, which heavily damaged the Gulf Coasts of Louisiana, Mississippi, and Texas. This article provides historical background on the Air Force Aerial Spray Unit and describes the operations in Louisiana in the aftermath of Hurricane Katrina.

INTRODUCTION

Human health has long been at risk from arthropod-borne diseases. Malaria, dengue, West Nile virus, and others continue to cause human health problems and create media attention. Military entomologists are acutely aware of the disease threat to deployed troops from insect pests, and have remained an integral part of the Department of Defense (DoD) since they were employed with excellent results to combat malaria in the South Pacific during World War II.[1] In that conflict, military entomologists quickly developed effective strategies to control mosquitoes and maintain troop health. One such method was the application of insecticides from aircraft to areas with high mosquito activity. Aerial applications of pesticides are an effective way of rapidly reducing numbers of potential insect vectors across large areas and in a relatively short period of time.[2-5] Unlike truck-mounted spray units or backpack sprayers, aircraft can access developed and undeveloped areas which are prone to arthropod outbreaks.

The Air Force has the mission to provide a fixed-wing, large-area, aerial pesticide application capability to control disease vectors, pest organisms, and undesirable/invasive vegetation, as well as treat oil spills in combat areas, on DoD installations, or in response to declared emergencies. In addition, DoD requires the Air Force to provide training to air crews and ground support personnel in the principles and practices of aerial pesticide application.

The Air Force Aerial Spray Unit (AFASU) traces its history back to early aerial applications of DDT during the later stages of World War II. After the end of the war, the Special DDT Flight was created in 1946, but was soon transformed to the Special Aerial Spray Flight (SASF) in 1947 when the Air Force became a separate armed service.[6] Eventually, as US military operations in Vietnam were reduced in the early 1970s, active duty Air Force assets were moved to reserve status, including spray planes returning from Operation Ranch Hand defoliation flights in Vietnam.[7] After more than 25 years at Langley Air Force Base, Virginia, the SASF was transferred from the active Air Force to the Air Force Reserve in 1973. Prior to this transfer, the SASF had sprayed for mosquitoes, Japanese beetles, and fire ants in various locations at the request of the Army, Navy, and other federal agencies. The move to the Air Force Reserve resulted in a change of location and designation. Relocated to Rickenbacker Air Force Base, Ohio, the unit was

referred to as the Spray Branch of the 907th Tactical Airlift Wing. In 1986, the Spray Branch began to transition from C-123 airplanes to C-130A airplanes and developed the modular aerial spray system for use in C-130E and H airplanes. The aerial spray mission was assigned to the 910th Airlift Wing at the Youngstown Air Reserve Station, Ohio, in 1991. Nonmilitary emergency aerial spray responses (and the targeted health threat) by Air Force aerial spray assets as part of the Air Force Reserve are shown in Table 1.

Table 1. Nonmilitary emergency deployments by the AFASU after transition to the US Air Force Reserve.

Year	Location	Health Threat	Coverage (acres)
1973	Panama	Equine encephalitis	37,600
1975	Guam	Dengue fever	157,530
1978	Azores	Japanese beetles	8,700
1983	Minnesota	Equine encephalitis	525,000
1985	Idaho	Grasshoppers	718,100
1987	Puerto Rico	Dengue fever	177,000
1989	South Carolina	Hurricane Hugo mosquito control	855,500
1992	Florida	Hurricane Andrew mosquito control	279,170
1999	North Carolina, Virginia	Hurricane Floyd mosquito control	1,700,000
2005	Louisiana, Texas	Hurricanes Katrina and Rita mosquito control	2,880,000

The AFASU trains for a primary wartime mission of protecting deployed troops from arthropod-borne illness by participating in ongoing mosquito control programs at different locations throughout the United States. By training in various geographic regions, the AFASU gains experience controlling different vector and nuisance species under diverse geographical and environmental conditions. The same measures are employed for herbicide applications. Some missions are designed for soil sterilization, such as at the Utah Test and Training Range, where large targets need to remain free of vegetation so that unexploded ordinance can be safely recovered. Other herbicide missions concentrate on habitat restoration, by lowering the dominance of invasive plant species, allowing native plants to recover and lowering the threat of wildfires. The AFASU has been involved with prairie restoration on the Saylor Creek Range, Idaho, combating the growth of cheatgrass (*Bromus tectorum* L.), and at Smoky Hill Air National Guard Range, Kansas, for the control of musk thistle (*Carduus nutans* L.). Table 2 lists the AFASU's current standing domestic operational commitments and the dates of inception for each.

As mentioned earlier, a modular aerial spray system (MASS) was developed for use with the C-130H airplane. The MASS, which has a maximum 2,000-gallon capacity for liquid materials, can be rolled on or off the airplane in approximately one-half hour. Functional in a variety of configurations, the MASS is useful for such applications as ultra low volume adult mosquito sprays (adulticiding), mosquito liquid larvicide sprays, herbicide applications, and oil dispersants for emergency cleanup of oil spills.

Ultra low volume sprays create an aerosol cloud of small discrete droplets that drift through the air. This type of application is referred to as a space spray since the goal is to drift droplets through a particular space resulting in contact with flying insects.[5] For this reason, the flight period of the target pests is one of the most important planning factors for missions using the ultra low volume configuration to control mosquitoes and nuisance flies.[8] Current methodologies for AFASU mosquito adulticiding use the MASS with booms placed through the fuselage doors. Those booms are fitted with flat fan nozzles positioned perpendicular to the slipstream of the aircraft for maximum shear and atomization of the sprayed liquid. This is especially important since the diameter of a droplet that effectively adheres to a mosquito is 10 μm to 25 μm.[9]

In contrast to space spray applications, deposition spray missions produce large drops which are intended to drop quickly onto a surface (eg, mosquito larvicide or herbicide application).

HURRICANES AND MOSQUITOES

In response to requests from state public health agencies, the AFASU has been tasked to control mosquitoes threatening human health or creating an unacceptable nuisance level in the aftermath of hurricanes (see Table 1).[10] However, following some

of these events, federal authorities, unfamiliar with mosquito biology, have questioned the local public health officials' requests for mosquito control, apparently unaware of a relationship between hurricanes and increased mosquito activity. Since the presence of mosquitoes following storms may surprise some, perhaps there is a valid question: do hurricanes create abnormally large mosquito populations? And, by extension, do hurricanes increase the risk of mosquito-borne illnesses such as encephalitides, dengue, and malaria?

Table 2. Current AFASU domestic operational commitments.

Location or Agency	Purpose	Year initiated
Langley Air Force Base, VA	Mosquito control	1973
Marine Corps Recruit Depot, Parris Island, SC	Biting midges and mosquito control	1983
Hill Air Force Base, Utah Test and Training Range	Clearing bombing range undergrowth	1983
US Coast Guard	Oil spill dispersants	1992
Smoky Hill Air National Guard Range, KS	Musk thistle control	1995
Mountain Home Air Force Base, ID	Cheat grass control	2000
Grand Forks Air Force Base, ND	Mosquito control	2001
Minot Air Force Base, ND	Mosquito control	2005

Since mosquito larvae develop in water, it is not difficult to extrapolate that a significant increase in potential breeding sites as a result of flooding from hurricanes would lead to a significant increase in mosquito populations. It is this premise that leads mosquito control personnel and vector ecologists to anticipate increased mosquito numbers following major storms. Logically, the presence of high densities of mosquitoes increases the potential for transmission of mosquito-borne disease. It is, however, important to define parameters for making such statements. Accordingly, we must identify the mosquito species capable of vectoring disease and determine if the pathogen is present in the resident mosquito population or enzootic hosts.

The destructive power of hurricanes creates a scenario in which mosquito populations are increasing at the same time many people are displaced or have had their primary shelters compromised. Exposure to mosquitoes is increased by the concentration of those displaced by the storm into temporary shelters, and by their activities as they search for food, construction materials, medical care, etc. Under such conditions, individuals may face maximum exposure to nuisance mosquito bites and mosquito vectors.

Mason and Cavalie[11] analyzed a malaria epidemic in Haiti following Hurricane Flora in 1963, observing an explosive increase in mosquito breeding brought on by heavy rainfall and extensive flooding. In this case, the researchers also tied an increased incidence of malaria to Hurricane Flora because all disease factors were present, including a heavy reservoir of gametocyte carriers, mosquitoes, and an exposed population (eg, people displaced and residual insecticide treatments negated by hurricane damage).

More recently, Gagnon et al[12] reviewed the incidence of malaria in El Niño years—which always include significant flooding conditions—in South America and found a significant relationship between flooding and malaria epidemics in northern Peru.

By contrast, in Honduras, Hurricane Mitch killed 6,546 people and displaced another 1.1 million from excessive rainfall and flooding.[13] Obviously this population was very exposed as a result of the displacement, but Campanella and Tarantini[14] found only a small increase in malaria cases between time periods preceding the arrival of Hurricane Mitch (statistically significant compared to 1997 but not to 1998). Likewise, O'Leary et al[15] did not find an increase in dengue in Federal Emergency Management Agency (FEMA) relief workers in Puerto Rico after Hurricane Georges in 1998. These researchers relate that 82% of the workers reported mosquito bites, but unfortunately they do not comment on the overall mosquito density during the study.

Experts are often questioned by the popular press and in some cases opinions on the hurricane-mosquito disease issue can differ markedly. For example, the *New Orleans Times-Picayune* quoted the State Epidemiologist of Louisiana as saying that heavy rainfall from hurricane Katrina actually killed adult mosquitoes, washed away larvae, and killed or

dispersed the birds that carry West Nile virus.[16] Without quoting a source, in 2006 Lauran Neergaard of the Associated Press stated somewhat contradictorily that "…recent research shows:… Hurricanes don't spur West Nile [virus mosquito vectors]. Instead, heavy rains temporarily flush out the tiny pools where mosquitoes have laid eggs. Yet the CDC [Centers for Disease Control and Prevention] fears that New Orleans and the Gulf Coast are ripe for a surge in West Nile this summer because of the rubble left by Hurricane Katrina last year, full of water-collecting crevices that make perfect mosquito breeding grounds."[17] Other news articles made contrasting statements. The director of the University of Minnesota Center for Infectious Disease Research and Policy warned that following Hurricane Katrina, rural areas could expect dramatic increases in mosquito numbers within 2 weeks, especially those areas where the storm left many pools of stagnant water.[18] Similarly, in October 2005, the *Houston Chronicle* [online] reports that, according to Texas A&M University entomology professor Jim Olson, floodwater mosquitoes take advantage of a direct hit from a storm in unique ways. They are able to hide in grass and avoid being blown away by wind. But when the storm surge hits, they ride it inland like surfers, into new territory. Further, Professor Olson says, "The hurricane actually concentrates them, it exacerbates the problem."[19] In comments to *The Rocky Mountain News* in September 2005, Dr Janet McAllister of the CDC described the mosquito problem 2 weeks after Hurricane Katrina as having reached "biblical proportions."[20] However, in the online discussions on the ProMED website, other contributors in the field suggested the opposite.[21]

In summarizing the above information, it appears that immediately following the landfall of a major hurricane, the mosquito problem may actually disappear or be minimized by intense wind, rainfall, and flooding. However, it is generally agreed that additional developmental habitat is created by such storms and, depending on environmental factors (temperature, rainfall, contamination, topography, etc), large numbers of vector and/or nuisance biting mosquitoes can be present in a period as short as 2 weeks.[22]

The American Mosquito Control Association and the CDC, along with a host of federal, state, and county level public health agencies, have worked diligently to convince FEMA to anticipate major mosquito outbreaks following hurricanes and other flood producing events and to develop strategic responses to such events. Developing a dialogue between federal and state public health agencies was one reason that the vector control aspects of the response to Hurricane Katrina were quick and decisive.

HURRICANE KATRINA

On September 8, 2005, the AFASU deployed to conduct aerial spray operations for mosquito and filth fly control in support of the FEMA Hurricane Katrina relief effort and were officially assigned to Joint Task Force Katrina on September 9, 2005. Two spray aircraft, a spare aircraft, and 3 crews set up at Duke Field, Florida, near Eglin AFB on the Florida panhandle. Duke Field was chosen because it was the closest fully-functioning military base with the logistical capability of supporting the C-130H spray aircraft. A total of 53 personnel were involved with the flying, entomology, maintenance, administrative, communication and life support issues relating to the AFASU response.

The extent of the damage caused by Hurricane Katrina is well known.[23] High winds downed trees and destroyed homes, while heavy rain caused extensive

The pilot of an Air Force Aerial Spray Unit C-130H airplane aligns the airplane onto the next flight line during an aerial spray mission over New Orleans, Louisiana, during post-Katrina operations in September 2005.

flooding. Storm-induced breeches in the New Orleans levee system resulted in the catastrophic flooding of approximately 80% of the city. Prehurricane evacuations had been incomplete in New Orleans and subsequent flooding exacerbated the problem by significantly increasing the difficulty of relief efforts. In early September, the full-scope of damage and level of human suffering was still unknown. News agencies reported potential human fatalities as high as 10,000 inside New Orleans, incidents of gunfire aimed at rescue aircraft,[24] and that EPA water tests showed E. coli levels were 10 times above safe levels.[25] Rapid mosquito and fly development was projected as temperatures reached 90°F during the day, and only cooled into the upper 70s (°F) at night. Filth flies, which have the potential to develop quickly in the type of habitat created in flooded New Orleans (eg, fecal contamination, muck, trash, animal carcasses) and move between unhygienic substrates and human food, potentially transferring harmful bacteria in the process, were considered to be the immediate insect vector public health threat by public health officials. Apart from filth flies, an additional concern for vector ecologists was that Louisiana already had a background of West Nile virus (WNV) circulating in mosquito pools and birds. By August 30, 2005, 40 cases of WNV had been reported in Louisiana, including 4 deaths. That was already more cases in Louisiana than in all of 2004.[26] By all accounts, Hurricane Katrina created enough damage to expose the population to potential vector and nuisance mosquito feeding. In particular, the absence of electricity, physical damage to living structures, and the use of temporary shelters by 200,000 displaced people combined to make these individuals vulnerable to mosquito bites and potential disease transmission. Similarly, intense mosquito exposure to rescue, cleanup, and utility repair crews, as well as law enforcement personnel was also projected. Thus, mosquito and fly control was considered a high priority in the strategy to protect public health.

The major crisis of the storm was the flooding of New Orleans. The recovery effort included a combined force from the military services, as well as other federal, state, and local agencies. The mission of the AFASU was to provide a stopgap measure to control mosquitoes until local mosquito control programs could resume operations. Hurricane Katrina had completely disabled normal mosquito control operations within the entire region south of Lake Pontchartrain. The damage ranged from various levels of equipment damage to the destruction of entire facilities. In one unusual example, spray trucks from Orleans Parish were pressed into service by an Army National Guard Unit. Further, employees of local Mosquito Control Districts (MCD) were themselves displaced by the storm. Air Force spray assets provided aerial vector control until MCDs could regain their normal operations or contracts could be established with private applicators. An additional complicating factor for nonmilitary aerial applicators was that the region had been designated as military controlled airspace, making spray activities by private applicators impossible at times.

The performance of aerial spray operations in and around New Orleans was complicated. The AFASU previously conducted spray operations during federally declared disasters but the situation in New Orleans was particularly challenging. To determine the vector threat, entomologists from the Louisiana Department of Health, CDC, and Air Force visited areas in and around New Orleans, conducted mosquito landing counts, surveys for filth flies, and directly consulted with bivouacking Army and Navy Preventive

An Air Force Aerial Spray Unit C-130H airplane during a vector control mission over New Orleans, Louisiana, September 2005.

Medicine Troops. This was the most effective means of evaluating the insect vector potential because the storm had severely limited communication between organizations conducting vector surveillance. Telephone and email service was erratic and troops continued to move around. In some cases, troops had deployed with insect surveillance equipment but had no time to put it to use because of higher priority tasks. Driving in New Orleans was difficult since many roads were still flooded or obstructed by debris. Also, military and police checkpoints were frequent. The few vehicles on the roads were limited to first responders—military, police, rescue, and utility repair. This was actually fortunate since few intersections had functioning traffic lights and general disrepair existed throughout the area. By driving to forward locations, surveillance data was gathered from Army and Air Force personnel from the Louis Armstrong Airport and Navy personnel from the Naval Air Station.

FLY CONTROL IN NEW ORLEANS

Timing insecticide applications with the period of maximum exposure of the target pest is a critical component of any pest control operation. Fly control began 3 hours before sunset to correspond with the diurnal activity of flies but avoid the warmest part of the day. Fuselage booms were equipped with 6 stainless steel flat fan TeeJet nozzles (size 8008) (TeeJet® Technologies, Wheaton, Illinois. 630-665-5000). Delivered by C-130H airplanes from a height of 150 feet above ground level using 1,000 foot wide lane separations (swath width), the organophosphate insecticide Dibrom Concentrate® (AMVAC Chemical Corporation, 4100 E Washington Blvd, Los Angeles, California, 90023) was applied at a rate of 1.0 fl oz per acre, as requested by the State of Louisiana Office of Public Health. Applications were made in Orleans Parish on 13 and 14 September, and again on 21 and 27 September, 2005.

Fly populations were monitored at 6 locations in Orleans Parish prior to the aerial spray mission on 21 September by the use of sticky fly paper outdoors for approximately 24 hours. Unfortunately, post-spray surveillance was not possible because military support for this activity had been evacuated in advance of Hurricane Rita. Nonetheless, entomologists on the ground in the New Orleans French Quarter observed heavy mortality in flies (sarcophagids, muscids, calliphorids, etc) within 15 minutes following the spray application. Flies that were resting on the sides of buildings or especially in trees near garbage piles were more impacted by the application than those flies under canopies or crawling around under the trash bags/piles. Environmental parameters were recorded as partly cloudy skies, light steady wind, 3 to 6 knots from the south and south-southwest, and temperatures ranging from 88°F to 82°F with no inversion layers. Such conditions are generally considered excellent for an aerial application. Preseley et al[27] found low numbers of muscid flies and mosquitoes in Orleans Parish during samples taken from 16 to 18 September, which may be testament to the success of these sprays. Aerial applications of Dibrom have been utilized against flies following hurricanes since 1961.[28] After Hurricane Camille, Dubose[29] reported mortalities in caged flies between 49% and 95%, where the lower range represents cages in protected locations versus higher mortalities from cages in exposed areas. It is assumed similar mortality rates occurred during these applications in Orleans Parish.

MOSQUITO SPRAYS BEYOND NEW ORLEANS

Mosquito sprays were also highly successful outside of the greater New Orleans area. In these cases, Dibrom was used at 0.5 to 0.75 fl oz/acre, depending on mosquito population densities. Flat fan nozzles (TeeJet 8005) were used on airplanes flying a lane separation of 2,500 feet. Lane separation was dropped to 1,500 feet in low wind conditions (<5 mph). Release altitude was 150 feet above ground level for all applications.

In Acadia Parish (September 29) the primary pest mosquitoes were *Psorophora columbiae* (Fabr.) and *Ps. ciliata* (Dyar & Knab) as determined by Acadia Parish Mosquito Control personnel who measured landing rates of these vicious biters at an average of 49 per minute (range 10 to 200, 22 sites). Wind was from the north at 6 to 8 knots, temperature was 84°F, and relative humidity was 60%. The spray application began 2 hours prior to sunset. A total of 169,764 acres were sprayed. An 88% reduction in mosquito landing rates was observed at these same locations the following day. This level of reduction was considered to be a borderline success since landing rates were still noticeable. In parish areas not sprayed, average landing rates were higher than the previous day (91 per minute; range 30 to 200, 22 sites). In response to increasing mosquito densities and the incomplete control from the September 29 spray mission, the

application rate was increased from 0.5 fl oz/acre to 0.75 fl oz/acre on 30 September. Environmental conditions were nearly the same as the previous night, northerly wind at 4 to 6 knots, temperature 84°F, relative humidity 60%. Again, spraying commenced 2 hours prior to sunset and a total of 139,156 acres were sprayed. Excellent control was achieved from the September 30 spray mission, and post-application landing counts were reduced on average by 99% (range of percent reduction 95% to 100%).

In all, a total of 1,942,607 acres in the following 12 Louisiana parishes were sprayed for vector and nuisance mosquitoes by the AFASU:

Acadia	Jefferson	Tangipahoa
Ascension	Orleans	Vermilion
Beauregard	Plaquemines	Vernon
Calcasieu	Saint Bernard	Washington

Increasing availability of private contractors, restoration of electrical power, and the assumption of normal mosquito control activities by MCDs led the Louisiana State Office of Public Health to release the AFASU on October 10, 2005. Additional AFASU spray missions continued in the state of Texas, where a total of 938,015 acres were treated.[30] As shown in Table 1, the combined total of 2,880,622 acres was the largest area treated since the AFASU was transferred to the Air Force Reserves.

CONCLUSION

The AFASU response to Hurricanes Katrina and Rita effectively illustrates why the unit was formed—to effectively minimize the occurrence of vectors and nuisance pests by treating large areas where such populations exist. This activity also demonstrates the need for military aerial spray assets in domestic situations where local vector control agencies were incapacitated or overwhelmed, and use of contract aerial spray assets was unfeasible because of severe airspace restrictions.

This deployment of assets was not done in a void. Without the assistance of state and federal agencies and their personnel, the deployment would have been extremely difficult, if not impossible. In fact, MCDs, state health agencies, and aerial spray contractors bore the brunt of public health and vector control activities following the AFASU's stand down and redeployment. However, this event demonstrates the AFASU's ability to fill a "stopgap" role in domestic emergencies such as that which followed Hurricanes Katrina and Rita, and its importance in civilian and military contingencies.

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Evolution of the Army Hearing Program

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POLICY DEVELOPMENT

Noise-induced hearing loss appears in literature as early as the 16th century when a French surgeon named Ambroise Paré described acoustic trauma in detail when he wrote of the treatment of injuries sustained by firearms.[1] Even so, the protection of hearing would not be addressed for 3 more centuries until the jet engine was invented, bringing long overdue attention and a flurry of policy development addressing the prevention of hearing loss.

In 1976, the General Accounting Office, now the Government Accountability Office, issued an investigative report.[2] This report identified over half of US government employees, including the Department of Defense (DoD), as working in environments with inadequate procedures for identifying and rectifying occupational health hazards. Further, the report requested that the US Congress amend the Occupational Safety and Health Act[3] to bring federal agencies under the inspection control of the Department of Labor. As a result, in 1978, military audiologists and other government employees achieved standardization in military hearing conservation with the publication of *DoD Instruction (DODI) 6055.12*,[4] which provides guidance and requirements for hearing conservation implementation.

To implement *DODI 6055.12*, the Army published a technical bulletin (*TB MED 501, Hearing Conservation*, now discontinued) in 1980. *DODI 6055.12* was updated in 1987 to implement new requirements established by the 1983 Federal Noise Amendment.[5] The new policy identified specific role responsibilities within a hearing conservation program and thereby paved the way for the first enforceable regulation to be published on the subject. The new, and current, implementing guidance is *Department of the Army Pamphlet 40-501, Hearing Conservation Program*.[6] This multifaceted approach to prevention has enjoyed many years of success until Operations Enduring Freedom and Iraqi Freedom, as illustrated in Figure 1. The large scale combat operations challenged this garrison-oriented prevention strategy. Figure 2 demonstrates that the majority of hearing loss in the Army is concentrated among those Soldiers involved in combat. Data about the percentage of Soldiers who returned from a combat deployment with significant hearing problems in 2004 are presented in Table 1. These hearing losses are the direct result of their noise exposure, and emphasize the importance of hearing protection for combat and combat training.

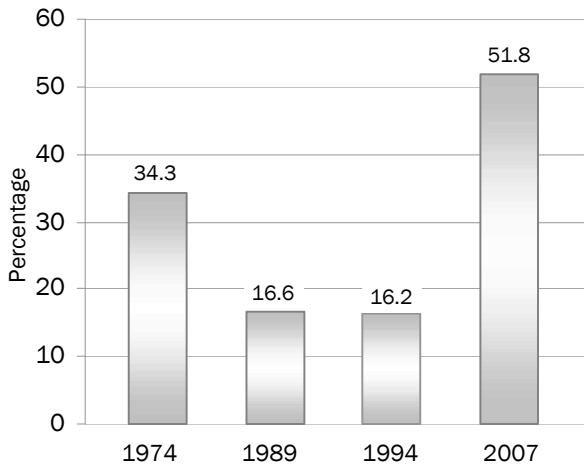

Figure 1. Percentage of US Army Forces Command Soldiers classified with H3 hearing profile* or greater, displayed by year to demonstrate the marked increase shown since the beginnings of Operations Enduring Freedom (October 2001) and Iraqi Freedom (March 2003).†

*H3 hearing profile is defined by the US Army *Standards of Medical Fitness*[7] as "speech reception threshold in best ear not greater than 30 dB HL, measured with or without hearing aid; or acute or chronic ear disease."

†Chart is a compilation of data from 3 studies.[8-10] (Source: http://chppm-www.apgea.army.mil/hcp//figures tables.aspx) and the Defense Occupational and Environmental Health Readiness System Data Repository, Comprehensive Hearing Threshold Database for the Dept of Defense, 2008. (Source://doehrswww.apgea.army.mil/doehrsdr/).

Annual data from the Department of Veterans Affairs (VA) evidenced the immediacy for implementing change by showing hearing as a primary disability.[12-14] In 2006, the VA awarded 55,864 new cases for hearing

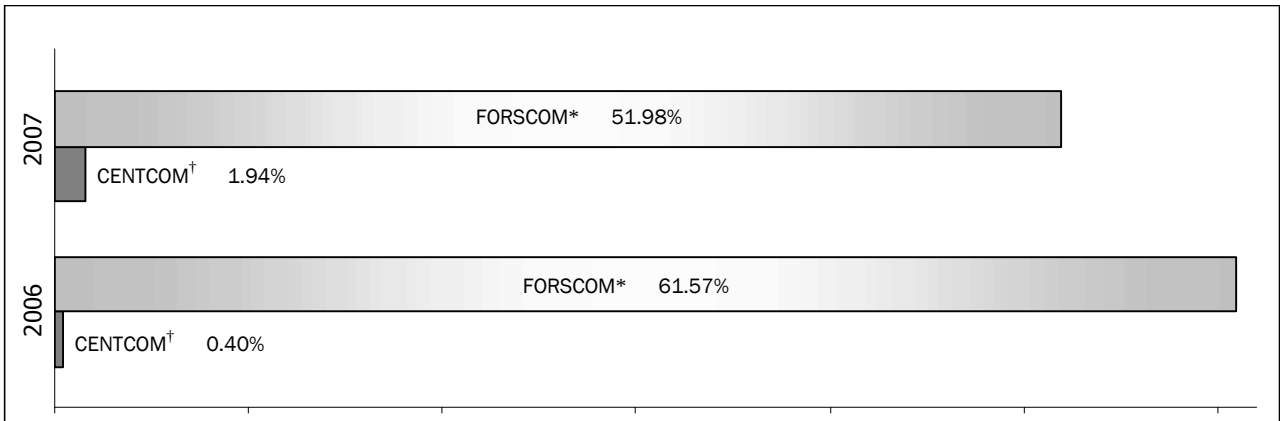

Figure 2. Percentage of Soldiers in FORSCOM* and CENTCOM† who tested at H2‡ and H3§ or greater hearing threshold levels in 2006 and 2007.** Overall, a much larger percentage of FORSCOM Soldiers are involved in combat operations, and the corresponding impact on hearing loss is clearly reflected in the data.

*Army Forces Command

†Army Central Command

‡Audiometer average level for each ear at 500, 1000, 2000 Hz, or not more than 30 dB, with no individual level greater than 35 dB at these frequencies, and level not more than 55 dB at 4000 Hz; or audiometer level 30 dB at 500 Hz, 25 dB at 1000 and 2000 Hz, and 35 dB at 4000 Hz in better ear. (Poorer ear may be deaf).

§H3 hearing profile is defined by the US Army *Standards of Medical Fitness*[7] as "speech reception threshold in best ear not greater than 30 dB HL, measured with or without hearing aid; or acute or chronic ear disease."

**Chart is a compilation of data from 3 studies.[8-10] (Source: http://chppm-www.apgea.army.mil/hcp//figurestables.aspx) and the Defense Occupational and Environmental Health Readiness System Data Repository, Comprehensive Hearing Threshold Database for the Dept of Defense, 2008. (Source://doehrswww.apgea.army.mil/doehrsdr/).

Table 1. Clinically diagnosed noise-induced hearing loss incidence rates among Soldiers, April 1, 2003, through March 31, 2004.*

Condition Diagnosed†	Postdeployment Related Diagnosis (n=806)	Nondeployment Related Diagnosis (n=141,050)
Acoustic trauma	45 (5.6%)	78 (0.1%)
Permanent threshold shift	236 (29.3%)	639 (0.5%)
Tinnitus	248 (30.8%)	2101 (1.5%)
Eardrum perforation	13 (1.6%)	88 (0.1%)
H3 or H4 hearing profile	127 (15.8%)	3140 (2.2%)
Any of the above	553 (68.6%)	5668 (4.0%)

*Data are from Helfer et al.[11]

†Diagnoses as coded in accordance with the *International Classification of Diseases, 9th Revision, Clinical Modification* (US Public Health Service).

loss alone. Between the starts of Operations Enduring Freedom and Iraqi Freedom, compensation payments for hearing loss increased by 319%. Hearing loss is the second most common new disability award by the VA, surpassed only by tinnitus. In 2007, hearing loss compensation reached over 1 billion dollars for a predominantly preventable injury. These figures do not account for service members who remain on active duty with hearing loss or those who may lose hearing in the future as a result of current hazardous noise exposure. Furthermore, the data presented are for primary disability only and do not include Veterans who have another primary disability rating, such as an amputated limb, in combination with hearing loss or tinnitus as a secondary disability.

ACCEPTING CHANGE

Whether in peacetime or wartime, hazardous noise exists as one of the primary occupational hazards in the Army. The risk of noise-induced hearing loss in Soldiers has reached the highest rate in over 30 years. This trend resulted from current combat operations, increased numbers of combat arms Soldiers, extended periods of weapons training, and deployment of new and more powerful noise sources from weapons systems, vehicles, and aircraft. US forces in Iraq and Afghanistan experienced a substantial number of blast injuries from improvised explosive devices, rocket-propelled grenades, and mortar rounds. These types of explosions remain the

single largest cause of injury from Operation Iraqi Freedom and comprise 47% of all medical evacuations.[15] As a result, developments in protecting Soldiers from these types of hazards are paramount.

The Combat Arms Earplug (CAE) is a nonlinear earplug that allows effective communication and situational awareness while providing protection from hazardous impulse noises. Introduced to the military by the start of Operation Enduring Freedom, Soldiers shunned them for operational use. Astonishingly, they were also considered cost prohibitive by the units at approximately $6 per pair. With units' strengths decreasing because of hearing loss, in 2004 the military began issuing CAEs to all deploying Soldiers and Marines. In fact, the Marine Corps was so convinced of the concept that they ordered over 20,000 pairs in 2004, temporarily depleting the entire national stock of CAEs. Anecdotal information from audiologists who served in Iraq indicated that no Soldier seen at a combat support hospital who reported that he or she was wearing the CAE when exposed to an explosion had ruptured eardrums.[16] The CAE is now a rapid fielding issue item for deploying Soldiers. The CAE allows most speech information to pass through with minimal attenuation, while protecting against noise associated with combat events. The CAE will soon become a standard issue item for all initial entry Soldiers, allowing them to train with the CAE prior to using them in combat.[15]

The Combat Arms Earplug
(Image courtesy of Aearo Technologies, 5457 W. 79th Street, Indianapolis, IN 46268)

Army Audiologists have been serving with combat support hospitals in Iraq since January 2004. Providing these reactive services in theater was logical, but the concept was not wholly sound because it neglected the need for prevention and maintenance of

Tactical Communication and Protective System

The obstacle of protecting hearing while enhancing a Soldier's communication ability and situational awareness is being addressed by a new generation of hearing protection. This new category of equipment is known as the tactical communications and protective system (TCAPS). TCAPS introduced a new category of electronic hearing protection that utilizes active noise reduction to soften noise, thus enhancing speech discrimination, while at the same time providing a noise reduction rate of up to 40 dB. In addition to being light and rugged, TCAPS devices provide protection and allow Soldiers to monitor environmental sounds, communicate, accurately gauge auditory distance, and localize sound sources without hindrance. Furthermore, some of these devices allow processing of military specific radio connections without signal interruption while reducing environmental sounds. QUIETPRO® (Nacre US Inc, 106 Bud Place, Aberdeen, North Carolina 28375), one of the TCAPS devices, is a rapid equipping force item. It allows both hearing enhancement and protection. The response from Soldiers has been extremely favorable, in fact, anecdotal information indicates that they do not want to deploy without them.

Also, Soldiers of the 4th Infantry Division, 3rd Brigade Combat Team are receiving QUIETPRO devices to use during their impending Operation Iraqi Freedom deployment. Audiologists are working closely with the 3rd BCT leadership to ensure that the devices are properly fitted to Soldiers, and they are trained on the devices. In addition, all Soldiers are provided predeployment hearing services, which include a predeployment audiogram, earplug fitting, and a health education briefing.

Quietpro® TCAPS Device
(Photo courtesy of Nacre US, Inc.)

Soldier hearing readiness while in a forward deployed environment. The paradigm of what composed a comprehensive hearing conservation program in the past has shifted, and now considers the Soldiers' environment on the battlefield. Operational hazardous noise situations that involved large military-unique equipment, lengthy work days, and immature infrastructure of base camps are addressed. Urban terrain—such as the streets of Baghdad—is a particular hazard for Soldiers because it is wrought with obstacles such as buildings, alley ways, and ditches. To compound the importance of good hearing, civilian inhabitants must be distinguished from actual combatants in an often chaotic environment.

A study was conducted by the US Army Human Engineering Laboratory in 1990 to investigate the effects of communications on performance.[17] The experiment, involving 30 experienced tank crews, required crews to conduct gunnery scenarios under communication conditions ranging from very good to extremely poor. Performance measures were recorded in different levels of speech intelligibility for each scenario, based on the modified rhyme test (a standardized intelligibility test). Five levels of speech intelligibility were used: 100%, 75%, 50%, 25%, and 0% intelligible. The specific measures used to evaluate performance as a function of speech intelligibility were mission time, mission completion, mission errors, and gunner accuracy. The scenarios consisted of 10 missions, each requiring the commander to instruct the gunner to shoot at up to 3 targets (21 targets per scenario). Four targets (tank, truck, helicopter, or troops) appeared during each mission. As is the standard operating procedure for armor operations, it was the commander's task to instruct the gunner to shoot at the appropriate target with the appropriate weapon. The results, displayed in Table 2, are compelling for the argument that the multidimensional sense of hearing provides an indispensable amount of information and could mean the difference between life and death on the battlefield.

Table 2. Results of the US Army Human Engineering Laboratory study of communication on performance of tank crews under simulated battlefield conditions (1990).

Function	Good Word Intelligibility	Poor Word Intelligibility
Time Required to Identify Target	40 Seconds	90 Seconds
Incorrect Command Heard	1%	37%
Correct Target Identification	98%	68%
Correct Targets Engaged	94%	41%
Incorrect Target Engaged	0%	8%

Data from Garinther and Peters.[16]

THE ARMY HEARING PROGRAM

The Army had to develop the means to prevent noise-induced hearing loss in Soldiers while ensuring their maximum combat effectiveness in training and during deployments. As a result, a contemporary model called the Army Hearing Program (AHP) was established. The AHP provides prevention services in a more fluid environment than that experienced in garrison.

As the Army transforms, the AHP will better meet the needs of Army civilians and Soldiers in all environments, especially those where the traditional hearing conservation approach does not. The AHP, an operational approach, provides hearing services to Soldiers in their training and operational environments. The AHP consists of 4 major elements: hearing readiness, clinical hearing services, operational hearing services, and hearing conservation. This combination of services promotes and increases Soldier awareness of hearing, and the importance of maintaining normal hearing for good situational awareness and voice communication in any environment, including combat. Due to current combat operations, the risk of Soldiers incurring noise-induced hearing loss is greater now than it has been in 30 years. Hazardous noise is one of the primary occupational hazards in the Army. As a result, AMEDD added authorizations for 10 badly needed Army Audiologists in 2007. These positions will have a positive impact on the Army Hearing Program, but will still place the inventory at a point that is one-third lower than it was in 1990.

Hearing services continue in the combat support hospital in support of Operation Iraqi Freedom. The prevalence of acoustic trauma is high in the combat theater, and commanders cannot afford to lose Soldiers to a medical evacuation for several weeks to determine their hearing status. In order to ensure hearing-injured Soldiers are provided immediate care, hearing sites have been established at all major forward operating bases in Iraq. Soldiers receive immediate hearing care

and follow-up services in-theater, and are quickly returned to duty.

CONCLUSION

Army-wide implementation of the AHP requires additional hearing resources to ensure both clinical and nonclinical hearing services are provided to Soldiers. In September 2006, hearing readiness was included in the Readiness Module of the Medical Protection System. Commanders and medical leaders can now monitor individual and unit compliance. Hearing readiness compliance for active duty Soldiers is currently 74%, a 15% increase since September 2006.[15] Funding is projected to fully implement AHP to bring hearing conservation into the 21st century, meeting the challenges of today's battlefield and that of the foreseeable future. The Army will no longer accept hearing loss as an inevitable byproduct of military service.

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Perspectives of Malaria and Japanese Encephalitis in the Republic of Korea

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An important aspect of vector-borne disease prevention is an understanding of how to defeat the host–reservoir–pathogen-vector cycle through vector surveillance. Surveillance may lead to new or improved vector identification information, revised vector checklists and distributions, new information about vector bionomics, or useful aspects of host-reservoir-pathogen-vector interactions. Over the past decade, Army entomologists and their Korean collaborators have significantly increased surveillance studies to update knowledge and answer questions about vector-borne disease impacts on potential military operations in the Republic of Korea (ROK).

The studies have attempted to increase our knowledge of pathogen-vector-host-reservoir relationships, primarily in terms of vector identification and bionomics, host behavior, geographical and seasonal distributions, and potential control or mitigation solutions. Vector surveillance is further augmented by human epidemiological investigations that identify human populations at risk, and disease distributions that can be correlated with relative vector importance. Country-specific knowledge was acquired through these studies to explain the human side of disease acquisition. Portions of this article condense the results of selected vector surveillance programs of the 18th Medical Command (MEDCOM), Yongsan, Korea, but, more importantly, focus on understanding Korea-specific disease issues.

MALARIA

During the Korean War, annual malaria rates ranged from 8.3 to 39.2 per 1,000 Soldiers.[1] In 1979, after years of eradication efforts, the World Health Organization (WHO) declared the ROK to be malaria free.[2] However, in 1993, a Korean soldier based near the demilitarized zone (DMZ) who had no recent travel history was diagnosed with vivax malaria.[3] This case was identified as autochthonous transmission that rapidly spread throughout the ROK troops stationed along the DMZ, and subsequently to local civilian communities. Based on WHO reports, North Korea experienced a similar resurgence of malaria, especially along the DMZ. While it was thought malaria in the ROK originated from North Korea, it soon became evident that malaria was again endemic in the ROK.[3-5] The Table presents the number of malaria cases reported annually in the ROK since 1993.

While malaria remains concentrated along the DMZ in northern Gyeonggi Province, other areas of the ROK are being affected as ROK veterans return to their homes and develop malaria resulting from latent liver stages.[6-8] Consequently, malaria spreads throughout the peninsula. In similar fashion, Koreans visiting northern Gyeonggi Province may acquire the disease, and then return to their home, elsewhere in Korea, after which the disease is expressed.[6-8] If the infective person (demonstrating fevers and chills) waits several days before seeking medical attention and is fed upon by vector mosquitoes, a focal point for malaria may have been created, and it may or may not survive for successive transmission or seasons.

In order to determine where malaria occurs, especially in military or transient populations, one must determine where the infective mosquito fed upon the affected person. Since it takes from 12 days to a year for vivax malaria to express disease (blood stage parasites), the locations of where the disease was expressed and where it was acquired are often completely different, especially among Soldiers who train along the DMZ, then return to their home base or are redeployed to the US or other countries. Therefore, detailed patient interviews by preventive medicine personnel trained in conducting epidemiological investigations/interviews are essential for quality data collection and determination of the site of transmission/infection. To achieve this, selected personnel in the Force Health Protection staff, 18th MEDCOM, conduct interviews and record and analyze

these data for all US military malaria cases diagnosed in the ROK.

Personnel who do not regularly work malaria issues may assume the area of disease expression is where the disease was acquired. This has lead to the implementation of corrective actions in the wrong area. For example, vector control actions may be implemented in areas with few vectors, and warnings may be given to bases or communities where malaria is very low risk. In other instances, unit leaders may think that they had a successful training event because no one contracted malaria during the event. However, they do not associate future disease expression as the result of inadequate protection, which many times can be traced back to the lack of command emphasis on personal protective measures (PPM) during their training event. The delay in the onset of symptoms blurs the direct cause-consequence relationship. Therefore, most people fail to associate their failures in protective actions with the consequences of contracting the disease.

Number of *Plasmodium vivax* malaria cases reported in the Republic of Korea (ROK) by year since 1993.

Year	US Forces Korea	ROK Military	ROK Veterans	ROK Civilians	Total
1993	1	1	0	0	2
1994	3	18	1	2	24
1995	1	88	12	7	108
1996	14	285	25	46	370
1997	33	1,156	207	361	1,757
1998	42	1,657	1,127	1,148	3,974
1999	58	1,084	996	1,541	3,679
2000	48	1,289	1,273	1,580	4,190
2001	30	673	748	1,067	2,518
2002	48	406	472	885	1,811
2003	30	273	274	560	1,137
2004	22	158	244	424	848
2005	17	233	322	769	1,341
2006	24	311	432	1,278	2,045
2007	34	447	462	1,271	2,214
Total	405*	8,079	6,595	10,939	26,018

*Distribution: US military - 361; Korean Army augmentees to the US Army - 43; DoD civilian - 1

Sources of data: Korea Center for Disease Control and Prevention, Seoul, ROK; Force Health Protection, 18th Medical Command, Yongsan Garrison, ROK.

Anopheles mosquitoes overwinter as eggs or nulliparous females (unfed females without eggs), which do not become infected until they feed on a person with circulating parasites. Therefore, the annual vivax malaria cycle is only maintained by a pool of latent malaria cases and asymptomatic carriers. As the temperature warms in late April to early May, the overwintering female mosquito takes a blood meal and lays eggs 3 to 5 days later with resultant increasing vector populations. These noninfected vector mosquitoes bite persons expressing the latent form of malaria, or untreated individuals who no longer demonstrate symptoms but harbor infective parasites, which in turn infect the new uninfected vectors. The vector population continues to increase throughout the summer and interactions with infective reservoirs and susceptible hosts assure that some of the parasites will be acquired and transmitted by the vector.

In rural areas along the DMZ, the probability of acquiring malaria in April or May is low, but steadily increases with peak transmission times occurring in late July and throughout August. During the peak period, the vector population is generally at its highest. Because there has been sufficient time during this period for vector-reservoir interaction, it is the older mosquito that is the dangerous mosquito (the period from ingestion of the parasite to transmission is a minimum of 9 days at optimal temperatures). Drainage of the rice paddies for harvest marks the downturn of malaria vector populations and results in a significant decrease in the number of malaria cases, which typically stop presenting in October or early November.

A number of factors, including droughts (reduction of breeding sites), heavy rain from monsoons and cyclones (mosquitoes washed downstream and older adult mosquitoes killed), pesticide/herbicide usage in the rice paddies (overhanging grasses along the banks provide habitat) affect population levels and the mean

age of the population that directly impacts on transmission levels. As many of these conditions are variable, they affect the number of malaria cases for any given year. For example, a very late autumn during 2006 resulted in a spike of malaria cases at the end of the malaria season and contributed to an increased number of latent cases the following year.

Only certain *Anopheles* species vector malaria. They feed sometime between dusk and dawn, and are often classified as primary or secondary vectors depending on their relative susceptibility to acquire salivary gland infections and interaction with human hosts, as some are zoophilic and prefer to feed on large animals such as cows.[9,10] Until 2005, *An. sinensis* was considered the primary malaria vector in Korea, and it was thought to be distinguished from other *Anopheles* species by morphological characters.

In 1999, while rearing progeny broods for the Walter Reed Biosystematics Unit (WRBU), two of the authors, COL Klein and Dr Kim, discovered that members of one sample demonstrated characteristics of 2 or more species. Subsequently, more progeny broods from wild-caught blood fed females were reared, and a selected fragment of the ITS2 gene was sequenced by polymerase chain reaction by a WRBU team and a researcher from the US Army Medical Research Institute for Infectious Disease to determine species and subsequently determine if morphological characters could be applied for their identification. In 2005, these teams of Army and Korean entomologists determined that *Anopheles sinensis* and closely related species consisted of at least 5 species: *An. sinensis*, *An. pullus*, *An. lesteri*, plus 2 new species: *An. belenrae*, and *An. kleini*, and further demonstrated that these species could not be reliably identified by morphological characters.[11]

These same entomologists, working with the Armed Forces Research Institute of Medical Sciences and the Korea National Institute of Health (KNIH), implicated *An. pullus* and *An. kleini* as the primary vectors of malaria, with *An. sinensis* having a lesser role.[10] Therefore, areas with relatively large populations of *An. pullus* and *An. kleini* should correlate with areas for the highest risk of malaria. Preliminary investigations, human-based surveillance, and larval and adult surveillance studies suggest that there is a valid correlation between the numbers of malaria cases and these primary vector populations. These studies are also working to determine if there is a separation of the larval habitat between these species, so control efforts can focus on selected habitats of greater importance rather than on large scale areas, which do not support large vector populations.*

JAPANESE ENCEPHALITIS

Japanese encephalitis (JE) is a viral mosquito-borne disease that can affect the human central nervous system, and may be fatal or leave people with mild to severe brain damage (neurological deficiencies). It is vectored by *Culex tritaeniorhynchus* in Korea and poses a greater threat south of Seoul where very large vector populations occur. Large water birds are the primary reservoir and swine function as amplifying hosts. Humans are considered to be dead-end hosts as they rarely develop sufficient viremia to infect mosquitoes. The disease is prevalent where wetland rice farming occurs, with population densities of vector mosquitoes peaking near the end of summer and early fall (August to early October).

Japanese encephalitis was first identified from an American Soldier at Inchon in 1946.[12] In 1949, JE became a notifiable disease and 5616 cases resulting in 2729 deaths (49%) were reported. After 1950, outbreaks of several thousand cases were reported periodically every 2 to 3 years. The largest outbreak occurred in 1958 with 6,897 cases. Since 1958, there were between 2000 to 3000 cases reported annually until 1968.[13]

In the mid to late 1960s, the Korean government instituted a massive JE immunization program for school-aged children which significantly changed the epidemiology of JE in Korea, but not the threat. Since the inception of the program, the number of JE cases dropped significantly, and for most years only a few sporadic cases (0 to 7 cases annually) have occurred over the past decade. In addition to the immunization program, a vast improvement of the environment, sanitation, and a higher standard of living contributed to the reduction of JE cases.

The relative proportion of symptomatic to asymptomatic (or mild unreported) cases is 1/25 to 1/1000 (and perhaps less in healthy young men), while

*See related article on page 46.

JE infections may result in severe morbidity with 10% to 30% mortality among those that demonstrate symptoms.[14,15] Researchers at the Department of Defense (DoD) Global Emerging Infections System and the Walter Reed Army Institute of Research are coordinating to evaluate pre- and postdeployment blood samples from Soldiers previously deployed to Korea to determine relative rates of transmission in lieu of no symptomatic cases reported among US Soldiers over the past 2 decades. Currently, the US protocol in Korea for JE vaccine categorizes inoculation as voluntary upon request by the individual.

Japanese encephalitis is maintained in the environment through a mosquito–large wading bird–mosquito cycle. The principal vectors prefer to feed on birds, but will feed on alternate hosts when birds are not available or when the alternate hosts enter the mosquitoes' habitat.[16] Pigs serve to amplify the transmission cycle, producing extremely high viremias that infect large numbers of the blood-feeding vector mosquitoes.[17] Japanese encephalitis infection causes spontaneous abortion in sows about to litter. For this reason, breeder sows are often immunized. However, because of the costs and the absence of effect on production, young pigs raised for slaughter are not immunized since virus infections do not affect their health or weight gain. When military personnel reside or train near vector mosquito habitats, such as rice paddies where large wading birds are present and especially near pig farms when JE is circulating, they are at high risk for infection. Therefore, risk assessments conducted for JE should consider the seasonality and proximity of swine farms to US military installations and training sites.

The KNIH conducts mosquito surveillance. When JE vector populations exceed 50% of the collected mosquitoes, the KNIH issues public JE alerts, reminds citizens to use all means to protect themselves from mosquito bites, and encourages high risk groups to obtain vaccinations. However, the areas where the Korean workforce conducts sampling are often not the same areas of interest as those of the US armed forces.

Additionally, the KNIH conducts sero-surveillance for the presence of JE antibodies/infection from slaughtered pigs at selected sentinel sites. The KNIH again reports the results in public news releases, which emphasize vaccination and PPM. However, these data do not reflect the focal infections since:

- sentinel sites are limited;
- only data from slaughterhouses are reported, not the pig farm sites where the transmission occurred; and
- pig farms are isolated and not evenly distributed.

While these data are limited, they serve as an early warning system. For example, prior to the immunization program, it was observed that approximately 2 weeks after the pigs were serologically positive for JE, mosquito samples were identified as positive, and shortly thereafter, focal outbreaks of JE in human populations resulted.

As the structure, distribution, and concentration of US military forces change in Korea in response to transformation and base closures, vector-borne diseases must be considered, for example, the movement of forces currently deployed north of Seoul to Camp Humphreys (near Pyeongtaek), which is programmed to become the primary US Army installation on the Korean peninsula. Currently, much of Camp Humphreys is surrounded by rice paddies—surveillance in 2005 and 2006 demonstrated large populations of *Culex tritaeniorhynchus* occurred from August through early October. The demographics of this installation will change from a Soldier based community to a Soldier and family member based community, placing family members, including young children, at risk in an area were they may be exposed to large populations of potentially infected vectors. In addition, 2 of 7 JE cases reported in the highly vaccinated Korean population during 2007 resided near Pyeongtaek, suggesting that implementation of a JE vaccination program is necessary to protect the susceptible and growing US population at Camp Humphreys. Thus, constant surveillance of mosquito populations, their infection rates, and coordination with the KNIH and Korea Center for Disease Control and Prevention is necessary to delineate the risks and reduce the threat of Japanese encephalitis to US populations.

Malaria and Japanese Encephalitis Prevention and Control Strategies

Readiness is a key issue with US military personnel in the ROK. The proximity and uncertainty of a rapidly

escalating enemy threat dictate that commanders and their Soldiers must be prepared for hostile actions and "train as they fight." This includes the prevention of disease and nonbattle injuries, especially those due to preventable diseases. Command emphasis and routine implementation of PPM is essential. It not only decreases the potential for malaria and JE transmission, but also decreases the probability of contracting scrub typhus and multiple tick-borne diseases. It also serves as an alert to commanders for other diseases (ie, Hantaan virus), where PPM and/or other strategies must be employed.

The prevention of mosquito-borne disease in endemic high-risk areas of the ROK requires strict adherence to the DoD Insect Repellent System, to include the mandatory use of bed nets during overnight field training events. In 2007, the Eighth Army purchased bed nets for use by military personnel who conducted overnight events in malaria high-risk areas near the DMZ. Barracks also replaced the tent village at Warrior Base and were thought to have an additional benefit of preventing vector⇔Soldier interactions. It was later observed that Soldiers would gather outside during off-duty hours and at night in shorts and t-shirts to socialize. Thus, their behavior exposed them to potentially infected mosquitoes, even though they all had the means to prevent mosquitoes from biting them and getting malaria or other diseases. Therefore, human behaviors continue to serve as major risk factors and cannot be overlooked.

Chemoprophylaxis (chloroquine with terminal primaquine) may be used to reduce the risks of acquiring malaria.[18] While it does not prevent transmission or infection, it does reduce the reservoir population (infective humans) required for the transmission of malaria to ROK civilians and US military personnel living or deployed in close proximity to ROK bases near the DMZ. However, an effective chemoprophylaxis program requires strict adherence to policy and observed compliance.[19,20] As a result of increasing malaria rates observed in US and ROK populations in 1998, the Eighth US Army placed all US Soldiers training near the DMZ on chemoprophylaxis. Commanders apparently did not understand the program as there were many variations (event and situational dependent), including noncompliance with terminal primaquine (15 mg daily for 14 days after the malaria season or when departing malaria high-risk areas). This resulted in an increased proportion of US diagnosed malaria cases being attributed to exposure in Korea.

Based on recommendations from the Preventive Medicine and Entomology Consultants, Force Health Protection, 18th MEDCOM, after 1999 the chemoprophylaxis policy was changed:

- Only those Soldiers residing in malaria high-risk areas (Camp Bonifas-Joint Security Area at Panmunjom and Camp Greaves) are placed on chemoprophylaxis.
- Command emphasis is placed on prevention using PPM that includes proper wear of the uniform, impregnating uniforms with permethrin, and using the standard military topical insect repellents while in field environments near the DMZ.

Efforts to combat mosquitoes with ultra low volume (ULV) or thermal foggers present several issues for US military forces in Korea. First, for various reasons, training areas are not treated, so PPM and other mitigation strategies must be employed in those areas. Second, US bases where mosquito-borne diseases are a threat are usually surrounded by rice paddies and as such are basically "islands" in a sea of mosquito habitat. Third, adulticides applied by ULV are effective over a short time and distance but do not significantly slow the migration of mosquitoes from the surrounding rice paddies. Fourth, pesticide resistance is a continual concern as some populations of mosquitoes are resistant to at least one of the pesticides used by the Korean health officials. Thus, health departments have resorted to a "cocktail" of insecticides rather than one specific type. However, it is thought that most mosquito populations are susceptible to pesticides currently used by the US military, although there have been no studies to confirm this supposition.

On bases, Soldiers tend to escape the affects of vector-borne disease because they are normally inside from dusk to dawn, the primary mosquito feeding times. Some bases are still located in urban areas where vector populations are low, further suggesting that the greatest risk for mosquito-borne disease is during overnight field training events. Planting vegetative borders along the perimeter of installations that are surrounded by rice paddies, then treating the

vegetation with semipersistent chemicals may reduce vector populations to acceptable levels. This reduction would occur as mosquitoes are killed when they come into contact with the pesticide while resting on the vegetation during their movement from off-post to areas where the Soldiers reside. Currently, none of the US installations or field training sites have perimeter vegetation that meet the requirements for barrier spray application and control, and, of course, the efficacy of this control strategy should be tested before full implementation.

Additionally, larval surveillance that identifies sources of vector populations on or near US installations must be conducted. On US installations, these sites must be identified on detailed maps to ensure control techniques are implemented (eg, drainage of water sources and application of larvicides) to reduce vector populations. If larvicides are applied to water sources, they must be surveyed periodically to ensure that they are effective. Pre- and postsurveillance must also be conducted when pesticides are applied to control adult populations, especially since preliminary observations of ULV application indicate that it is effective for less than one hour after application.

New Jersey light traps (NJLT) have been used for mosquito collection since the end of the Korean War. These traps use light as an attractant and therefore require light security where they are employed. Also, due to security at US military installations, there are few places where lights which interfere with the collections of mosquitoes are not present. Because light is used as an attractant, all insects attracted to lights (ie, moths, flies, beetles) are collected, which results in damaged mosquito specimens that cannot be identified. Furthermore, a killing agent is placed in the collection chamber that rapidly kills mosquitoes, rendering them useless for virus isolation. However, newer innovative mosquito traps have been evaluated that do not depend upon light security, collect larger numbers of mosquitoes, and collect mosquitoes alive so that virus infection rates can be determined.

For example, the Mosquito Magnet®, uses CO_2 and heat as attractants and selectively collects mosquitoes. Octenol can be added as an attractant and acts to attract more of some species, but repels others (eg, *Culex pipiens* and *Culex orientalis*). In general, more *Anopheles* mosquitoes are captured in the Mosquito Magnets using octenol than in other mosquito traps, but the increased attraction/repellency has not been determined for each species. While these traps provide many advantages—portable, can be used in areas without electricity such as field training sites, collect large numbers of mosquitoes, live-capture mosquitoes in relatively good condition so they can more easily be identified and used for virus isolations—over the stationary NJLT, they require propane (an explosive gas) and must be secured. Results of the use of Mosquito Magnets demonstrated their utility in the identification of JE infection rates in mosquitoes as high as 3.3/1,000 and 0.3/1,000 at Warrior Base; thereby identifying the focal transmission and epidemic potential of this virus.

CONCLUSION

Vivax malaria and Japanese encephalitis remain valid threats to military populations in Korea. The primary threat of malaria is north of Seoul and along the DMZ. Travel history within Korea is important in understanding Korean malaria issues, and leaders must remember to determine the site of transmission and not the site of diagnosis when implementing prevention and control measures. Recent studies have provided new information on the acute and latent forms of Korean malaria, the identification of new *Anopheles* species, and the incrimination of potential malaria vectors and their habitats.

Japanese encephalitis continues to circulate in avian and swine populations. Korean vaccination programs have significantly reduced Japanese encephalitis expression in humans. However, with the movement of US military dependent populations to Camp Humphreys, the US military Japanese encephalitis vaccination and prevention policies for this susceptible population must be reevaluated. Studies are needed to determine practical control strategies for "island populations" of susceptible hosts, such as are found on some US military installations in Korea.

Finally, military organizations performing vector surveillance studies in the ROK should coordinate their visit with the Force Health Protection staff at the 18th MEDCOM and the 5th Medical Detachment. These organizations currently have resources and collaborations for in-country support on the identification of vectors, rearing immature vectors to

the adult stage, information regarding malaria interviews, and collaborative support with Korean health organizations and universities.

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Health Implications of Occupational Environmental Health Sampling

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One of the legacies of the military campaign in the Persian Gulf is the realization that the public health toll of a conflict is not truly known at the time the deployment ends. Concerns regarding delayed health effects may extend the medical mission for years. In a January 2003 *Washington Post* article, David Brown[1] described a "new system to keep health syndromes at bay." He noted that "the agonizing investigation of what came to be known as Gulf War syndrome eroded trust in the military, cost hundreds of millions of dollars and consumed thousands of years of human labor." Brown acknowledged that the inability of the military to provide answers to questions relating to exposures, troop location, false chemical alarms, and predeployment health status among other concerns fueled a belief that

> …horrible things may have occurred during the war.… military health officials and most civilian researchers who studied the subject do not believe anything unusual or undiscovered occurred in the Gulf War to cause chronic illness. This time, the military is determined to begin and conclude the conflict with much better information.

Brown also addressed the information that is being collected to characterize occupational and environmental exposures, and its potential uses.

The Evolution of the Occupational and Environmental Health Assessment

Efforts to characterize occupational and environmental health (OEH) exposures in deployed settings have matured substantially. During the deployment to the Balkans, health surveillance policy stressed a need to identify health threats in theater, routinely and uniformly collect and analyze information relevant to troop health, and disseminate this information in a timely manner. US Army preventive medicine personnel collected air, water, and soil samples from a variety of locations, largely out of concern about industrial contamination. The ambient air was monitored for volatile organic compounds, semivolatile organic compounds, particulate matter less than 10 μm in diameter (PM 10), and associated metals. The main source of particulate was coal-fired power plants. Sampling indicated intermittent detections of volatile components of fuel at concentrations that were not sufficient to produce acute health effects, and, the potential for chronic health effects was considered minimal due to intermittent exposures at varied locations. At one location near a lead smelter, ambient sampling indicated elevated levels of lead. Blood lead testing was performed to assess exposure of the Kosovo Peacekeeping Forces. Fortunately, the smelter ultimately closed. Nearly 600 PM 10 samples were taken and compared to US Environmental Protection Agency (EPA) Air Quality Index levels. Sixty percent of the samples were in the good category, where no health effects are expected. Another 38% were in the moderate category, with less than 2% categorized as unhealthy for sensitive groups or unhealthy in general.[2] These categories and corresponding levels are used in the US to alert the population and sensitive subgroups such as elderly, children, and those with heart and lung disease when outdoor activity could be hazardous to their health.

Limited environmental regulations allowed pollution of surface waters with raw sewage and industrial wastes. While US forces drank bottled water, water for cooking, laundry, and showers was produced locally by reverse osmosis water purification units and treated municipal supplies. Finished water did not exceed any of the US Environmental Protection Agency (EPA) primary drinking water standards. Soil sampling was also performed and compared to the EPA risk-based guidelines, and, given the limited duration of exposure, no concerns were noted.

Anticipation and Hazard Recognition

The current OEH assessment process focuses on hazard anticipation as well as recognition. Prior to the location of a site, planners can request a preliminary hazard or Phase I assessment from the Global Threat

Assessment Program.* This process identifies industry and other relevant features of a location, past use and practices, as well as available intelligence. This can be used to guide in the selection of a location, and to focus the Occupational and Environmental Health Site Assessment (OEHSA). One of the initial actions taken by preventive medicine personnel upon arrival at a site is the OEHSA. This is an overview of the location that surveys potential health risks, samples soil and water, and investigates focal concerns such as stained soil that might indicate a fuel spill, stored or discarded toxic material containers, or problems from local industry or operations. These findings are summarized and serve as a starting point for periodic base camp assessments. While the actual sampling frequency and extent may vary with the size of the camp, the location, or its population, a typical analysis includes soil and water samples which are analyzed for pesticides, volatile and semivolatile compounds, and metals. Current technology analyzes for presence of compounds, identifies those present, and quantifies the amount. Typically, ambient air sampling, noise, and entomological and radiation surveys are also conducted. The results are stored in the Defense Occupational and Environmental Health Readiness System† (DOEHRS) data portal, maintained and operated by the US Army Center for Health Promotion and Preventive Medicine (USACHPPM).‡

USACHPPM's Role in Occupational and Environmental Health Surveillance and Support

The USACHPPM provides consultative assistance, equipment, and analytical support to deployed preventive medicine units. Standardized guidance documents and decision criteria provide a framework for hazard identification, exposure monitoring, and operational risk assessment. USACHPPM also provides training on the use of technical guidance and environmental monitoring equipment. OEH hazard data is archived along with the geographic location. Since 2005, ambient sampling data linked to a base location can be matched with a roster of the base camp population to identify a population at risk. Presently, the USACHPPM data archives holds tens of thousands of sample results. These may exist as spreadsheets of data consisting of various concentrations of unfamiliar compounds tied to a location, without a clear connection to a defined population at risk or known exposure durations. Clearly, interpretation must occur before this information is useful for any consideration of impact to health.

During the 1990s, the USACHPPM attempted to identify existing exposure guidelines to use for comparative purposes. Occupational exposure values exist for many compounds, for example, the Threshold Limit Values, or TLV's, which

> …refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects.[4]

Some are near-effect levels based on studies of workers, in settings where monitoring of industrial hygiene documented exposures. Others are based on scarce toxicological data and extrapolations. As a whole, the quantity and quality of data on which they are based varies, resulting in differing levels of uncertainty. These occupational guidelines are typically used to determine when a worker should be enrolled in medical surveillance. They are also used by industrial hygienists to determine if exposure reduction is needed, and if controls, including personal protective equipment, should be implemented. Another source was those guidelines created for use in environmental assessment and cleanup. These often assume a 24-hour, daily, lifetime exposure, and are typically derived to protect children, pregnant women, and other sensitive populations. These are not effect levels, but conservative guidelines which include safety factors that can serve as "clean-up goals" before locations are considered acceptable for unrestricted access, or use as a home site or park. Additionally, short term exposure guidelines exist for acute events such as a chemical release. None of the guidelines entirely address the deployment exposure scenario—a

*The Global Threat Assessment Program, a function of USACHPPM, identifies and assesses deployment OEH hazards and threats for worldwide priority deployment areas, both existing and planned. These assessments are used by the OEH surveillance activities that support the intelligence preparation of the environment during operational planning.[3]

†Defense Occupational and Environmental Health Readiness System is an integrated environmental, safety, and occupational health application supporting Department of Defense initiatives to capture, store, and analyze the exposure history of military-related personnel throughout their life. Source: DoD Health Affairs. Available at: http://www.ha.osd.mil/peo/ritpo/ritpo_01.asp

‡Available at: https://doehsportal.apgea.army.mil/doehrs-oehs/ Authorized users only.

relatively fit, healthy force, potentially exposed 24 hours per day for a roughly 12 to 15 month period or less. Additionally, sampling indicates a point exposure, but any one individual is unlikely to be at any spot on a base camp for 24 hours per day. Therefore, existing guidelines were modified to derive the Military Exposure Guidelines.

From Concentrations to Conclusions

Military Exposure Guidelines (MEGs), are screening levels for specified exposure durations, for hundreds of chemicals in air, water, and soil. These screening levels are found in the USACHPPM *Technical Guide 230* [5] and were derived from existing levels established by other organizations, such as the EPA, or occupational standards, as discussed above, modified to fit the deployed population and time frame. As with any guideline, its use necessitates an understanding of whether it represents a screening level or an action level. For example, when exceeded, some occupational levels necessitate a specific action on the part of an employer which might be to control or reduce the exposure and potentially initiate a medical action. In contrast, screening values, such as those used by the EPA in environmental assessment, are conservative and thus an exceedance is an indication that further evaluation may be necessary, that some remediation should occur, etc. However, an exceedance is not likely to indicate a specific medical action for any individual or population. Other values that have been derived for emergency planning purposes also have some safety factors built in, but the uncertainty is usually less, so exceedances may be associated with specific actions. The MEGs are screening values, not action levels, and were reviewed by the Committee on Toxicology of the National Academy of Sciences as part of the Department of Defense (DoD) approach to OEH assessment. The Committee considered them appropriate force protective screening values, useful to provide information to a commander and to guide further actions. On the other hand, the Committee agreed that MEGs were not casualty estimates and that exceedances did not indicate that a health effect was likely in the exposed population.[6] This point is often missed or misunderstood, particularly in the context of medical actions, documentation, and potentially long-term surveillance and compensation.

So what is the appropriate use of a Military Exposure Guideline in OEH assessment? When a contaminant is measured above the MEG appropriate for the presumed duration of exposure—there are short-term and long-term MEGS—there is some "space" for evaluation. This is done by looking at potential health effects associated with measured levels. Given that the screening guidelines have some built-in safety factors, there may be no health effects. This step identifies the health severity. The next step is to examine the likelihood of exposures and probability (number of samples, etc). Once a health threat has been identified and its health severity and probability determined, the risk is compared to others in the process of operational risk management, a process for identifying, assessing, and controlling risks from operational hazards, including OEH hazards.[7] Risk is determined by estimating the probability and severity of a potential adverse impact that may result from hazards due to the presence of an adversary or some other hazardous condition (ie, environmental contamination). Risks range from low through extremely high. For example, the Army's OEH hazard operational risk management (ORM) assessments for 2005 are presented in Table 1.

Leaders seek to mitigate risk by evaluating hazards and implementing ORM options during operational planning. When applied by medical personnel, the ORM process allows planners to include the assessment of the severity of hazards, characterize the risks in the context of the proposed operation, and then effectively communicate the risk assessments and appropriate control measure options to the commander. Commanders then make informed decisions by balancing the OEH risks and other operational risks with mission requirements. Given that ORM is intended to focus on operational risk to a mission, OEH exposures with acute effects and impact are weighted more heavily.

Acute versus delayed health risks

Typically, acute exposures are characterized as high enough to cause an effect immediately, or in the short term (hours or days). While they are easier to measure, and easier to interpret and relate to a health effect, it may be less likely that monitoring information exists because they are often unanticipated. Examples might include a fuel spill impacting water, a release of metals or other chemicals due to a fire or burning of materials, or an emission from industry due to less stringent controls or diminishing infrastructure. Hazards associated with acute effects may impact

Table 1. US Army Occupational and Environmental Health Operational Risk Management (ORM) Assessments Performed During Calendar Year 2005.

US Unified Command Country Involved	Number of ORM Assessments	Low Risk	Moderate Risk	High Risk
Central Command				
Afghanistan	60	50	8 Ambient air based on PM10* 2 Treated water quality	
Djibouti, Egypt, Kenya, Ethiopia, Kyrgyzstan, Uzbekistan, United Arab Emirates, Yemen, Saudia Arabia	31	24	2 Ambient air based on PM10* 2 Treated water quality	
Iraq	195	125	57 PM10* and metals 9 Treated water quality 2 Raw water quality	2 PM10* and lead
Kuwait	37	20	16 Ambient air based on PM10*	1 Treated water quality
Qatar	11	9	2 Ambient air based on PM10*	
European Command				
Bosnia, Georgia, Kosovo (Serbia), Morocco	5	4	1 Raw water quality	
Southern Command				
Antigua, Belize, Dominican Republic, Columbia, Grenada, Guatemala, Haiti, Honduras, Netherlands Antilles, Nicaragua, Panama	17	12	1 Water quality 1 Bottled water 2 Ambient air based on PM10*	
Northern Command, Joint Task Force, Katrina				
United States	136	133	2 Ambient air based on PM10* 1 Treated water quality	
Totals	492	378	92 Ambient air 19 Water quality	2 Ambient air 1 Water quality

*Particulate matter less than 10 μm in diameter

operations, and as such are given a higher operational risk than hazards with delayed effects. However, a memorandum issued by the Joint Chiefs of Staff in November 2007,[8] introduced new hazard severity categories for use in ORM that address both acute and chronic effects. Those severity categories are presented in Table 2.[8(pB-9)] The intent was to inform commanders of the potential effects that might not impact the operation, but which might be force health protection considerations. This supports the DoD requirement to document exposures that can cause latent health effects and, when indicated, conduct long-term medical surveillance.[9] It is quite difficult to meet this requirement if a provider does not have access to the data or the interpretation.

Lower levels of hazards which may pose a chronic risk, or contribute to or cause a delayed health effect are substantially more complicated to evaluate. It is more likely that routine, nonincident conditions generate levels that are relatively low, but may on occasion reach levels that, if sustained, could pose a chronic risk. However, this requires relatively constant exposure to these levels. Levels that are not high enough to pose an acute risk, but high enough to be of concern for chronic exposure may or may not be typical or sustained. Additionally, defining the population who would experience a sustained exposure is difficult since people move, exposure conditions are more likely to be variable then constant, and sampling is most often intermittent. However, long term MEGs

Table 2. Operational Hazard Severity Ranking for Occupational and Environmental Health Hazards During Military Deployments.

	Operational Severity Rank				
	None	Negligible	Marginal	Critical	Catastrophic
	Acute Effects†				
Description of Types of Health Effects Drivers for Severity Category*	No effects are anticipated	Few exposed personnel (if any) are expected to have noticeable acute health effects during mission. Exposed personnel are expected to be able to effectively conduct all basic functions during mission operations. Minimal to no degradation of abilities to conduct complex tasks are expected.	Few exposed personnel (if any) are expected to have noticeable acute health effects during mission. Exposed personnel are expected to be able to effectively conduct all basic functions during mission operations. Minimal to no degradation of abilities to conduct complex tasks are expected.	Many personnel are expected to have acute disabling/incapacitating health effects that require immediate medical treatment or support (eg, are considered casualties.) There may be limited numbers of fatalities. Personnel not experiencing these more serious acute effects are expected to have at least noticeable, but not disabling, health effects. Many personnel will have limited ability to conduct basic tasks, though complex skills may be significantly degraded.	Many casualties with severe acute disabling/incapacitating effects requiring immediate and significant medical attention and/or additional support for survival. Increasing number of deaths. Exposed personnel unable to perform basic physical and/or mental functions.
	and/or	and/or	and/or	and/or	not a driver
	⇩	⇩	⇩ **Chronic Effects‡**	⇩	⇩
	No effects are anticipated	Few exposed personnel (if any) are expected to develop delayed onset, irreversible effects.	Many exposed personnel are plausibly expected to develop delayed onset, irreversible effects. While this may not affect the immediate physiological capabilities of individuals, commanders must consider long term implications and appropriately communicate the resulting risks. Psychological implications may adversely impact operations particularly over extended operational periods.	Majority to all exposed personnel are plausibly expected to develop delayed onset, irreversible effects due to the specified exposure.§ While this may not affect the immediate physiological capabilities of individuals, commanders must consider long term implications and appropriately communicate the resulting risks. Psychological implications may adversely impact operations, particularly over extended operational periods.	This level of hazard severity is reserved for the most serious of conditions where immediate survivability against acute effects is the priority. Those that survive exposures may be at increased risk for certain chronic hazards.

*Effects associated with a chemical are typically either acute or chronic, but in some cases may be both. In general, short term single exposures are primarily associated with acute effects, while repeated long term exposures are associated with chronic effects. The ORM risk assessment process requires decisions to be based on the most operationally significant risk which is generally due to acute health effects. However there are certain circumstances where a chronic irreversible health effect may drive the ORM decision-making.

†Acute effects: Have relatively immediate onset (seconds to hours). While acute effects caused by a hazard are typically reversible, chronic effects may occur secondarily depending on type of hazard and severity of acute effect.

Examples:

Noticeable but not disabling eye/upper respiratory irritation, cough, mild gastrointestinal upset, general malaise

Disabling/incapacitating- difficulty breathing, severe nausea/diarrhea, impaired vision; Severe - pulmonary edema, seizures, coma

‡Chronic effects: Typically have a delayed onset (months to years) and are generally considered irreversible. Examples: cancer, chronic lung or liver disease, neurological damage.

§Particularly since there is substantial variability/uncertainty with the scientific evidence between certain occupational/environmental exposures and chronic health effects, the severity ranking must factor in the scientific weight of evidence supporting the link between the specified hazard exposure and the specific irreversible effect/disease.

are screening values for more chronic effects and the measured exposure would need to be sustained for long periods. Therefore, actions can be taken to reduce or mitigate the exposure. Typically, follow-up sampling indicates that the exposure is not likely to be sustained, and the long term MEG is not exceeded on a long-term basis. In the event of a significant risk for a delayed health effect, efforts to identify the exposed population at risk and conduct medical surveillance or epidemiological studies could be initiated.

DOCUMENTATION OF EXPOSURE AND ACCESS TO OEH EXPOSURE INFORMATION

Documentation of "significant OEH exposures" in the individual medical record has been required by DoD[9(p8)] for some time. In reality, although data collection has occurred, the content and method of such documentation has been a subject of some debate. "Significant" is not defined in the document, although one line states that exposures "…that result in an acute illness or that have potential to cause latent illness will be included in the patient records of those individuals affected or possibly exposed."[9(p12)] The aforementioned Joint Chiefs of Staff memorandum specifies the need to document "significant occupational and environmental exposures," and defines those exposures as "…exposures that will plausibly result in clinically relevant adverse health outcomes to exposed individuals."[8(pA-3)] While it is likely that individuals who seek care for an acute illness will have documentation in their medical records, it is possible that no sampling was available for the incident. The requirement to include OEH exposure data related to potential delayed effects necessitates the assembly and summarization of long-term sampling data. OEH data files are large and do not lend themselves to inclusion like a lab slip or industrial hygiene sample. Additionally, many providers believe that long-term, ambient, population-level data, as opposed to individual or personal samples, do not belong in a medical record, but are more appropriate for epidemiological studies. Finally, many providers are unfamiliar with the compounds and the basis of screening guidelines and would not necessarily be able to use the information to take specific actions.

US Air Forces Central* created Environmental/ Occupational Health Workplace Exposure data forms that are prepared by bioenvironmental engineers and reviewed by medical personnel. As Army and Air Force units are often collocated, Army personnel have sometimes requested documentation, and the Army preventive medicine units in the field have generated Standard Form (SF) 600s† for some sites. An example of one such SF 600 for a location in Iraq is provided on page 80. A subgroup of the Joint Environmental Surveillance Working Group,‡ working with the US Central Command Surgeon's office and preventive medicine organizations in theater, identified the types of entries in the SF 600 made by the military services to date, and is identifying the format and data elements to promote consistency. USACHPPM has initiated a parallel procedure to create site summaries from the ORM reports completed for base camps that are shorter and can be used by a physician who desires information about a base camp, an interested Soldier, the US Department of Veterans Affairs, or deployed preventive medicine units that are creating the SF 600s. Additionally, full ORM reports, sample results by location, and other information are still accessible to anyone with a desire or need to know through the DOEHRS. These efforts to distill and layer information for archiving should make the information manageable and useful for those who need only a summary with the identification of any concerns. Throughout the process, the identification of potential long-term concerns can be documented and archived for current or future use. As these efforts continue and progress, providers will become familiar with the types of OEH health risks evaluated in theatre, and can use this information for communication with patients, and in the evaluation of individual patients. Requests for assistance and consultation can be obtained from the Environmental Medicine Program at USACHPPM (http://chppm-apgea.army.mil).

*The US Air Force component of US Central Command

†Chronological Record of Medical Care

‡The Joint Environmental Surveillance Working Group was established in 1997 by the Assistant Secretary of Defense (Health Affairs). It serves as a coordinating body to develop and make recommendations for DoD-wide OEHS policy. The working group includes representatives from the Army, Navy, and Air Force OEHS health surveillance centers, the Joint Staff, other DoD entities, and VA.

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THE US ARMY CENTER FOR HEALTH PROMOTION AND PREVENTIVE MEDICINE

PREVIOUS EDITION IS USABLE — PREVIOUS EDITION IS USABLE

MEDICAL RECORD	CHRONOLOGICAL RECORD OF MEDICAL CARE
DATE	SYMPTOMS, DIAGNOSIS, TREATMENT, TREATING ORGANIZATION (Sign each entry)

02 August 2007

OIF ENVIRONMENTAL/OCCUPATIONAL HEALTH WORKPLACE EXPOSURE DATA
Camp Slayer/ Victory Base Complex (VBC), IRAQ

PURPOSE: To comply with the deployment health surveillance requirements of Presidential Review Directive 5, AUG98; MCM-0006-02, Updated Procedures for Deployment Health Surveillance and Readiness, FEB02; Department of Defense Instruction number 6490.03, 11AUG06.

Hazard determination was based upon environmental sampling conducted by the 61st Medical Detachment (Preventive Medicine), the 898th Medical Detachment (Preventive Medicine), and the 12th Medical Detachment (Preventive Medicine). Environmental samples collected were limited in time, area, and media and therefore, should not be considered a complete assessment of the overall occupational and environmental health hazards to which service members were exposed at this location.

This documentation does not imply cause of medical problems or levels of disability. It is for historical exposure purposes only.

ENVIRONMENTAL EXPOSURE SUMMARY (USACHPPM Tech Guide 230, JAN02 and FM 5-19 Composite Risk Mgmt, JUL06):

Environmental Exposure to:	Severity (Effect)	Probability of Exposure	Occupational and Environmental Health Risk	w/ Mitigation
Air Contaminants				
Particulate Matter (less than 10 microns in size)	Negligible	Occasional	Low	Low
Metals	Negligible	Unlikely	Low	Low
Soil Contaminants	Negligible	Unlikely	Low	Low
Water Contaminants	Negligible	Unlikely	Low	Low
Endemic Diseases				
Leishmaniasis (Cutaneous)	Marginal	Seldom	Low	Low
Leishmaniasis (Visceral)	Critical	Unlikely	Low	Low
Malaria	Critical	Unlikely	Low	Low
Tuberculosis	Negligible	Unlikely	Low	Low
Rabies	Catastrophic	Unlikely	Moderate	Low
Noise (8-hr TWA above 85 decibels)	Negligible	Seldom	Low	Low
Heat Stress	Marginal	Frequent	High	Moderate
Cold Stress	Negligible	Seldom	Low	Low

Note: Camp Slayer is located in central Iraq, west of Baghdad, and was formerly the Saddam Hussein Palace Complex. The base occupies 4.9 km². Surrounding Camp Slayer are agricultural areas, residential neighborhoods, US camps, and Baghdad International Airport.

MEDICAL PROVIDER:
Name (print/stamp):
Signature:
Email Address:
DATES OF SOLDIER'S DEPLOYMENT:
From: _____
To: _____

HOSPITAL OR MEDICAL FACILITY	STATUS	DEPART./SERVICE	RECORDS MAINTAINED AT
SPONSOR'S NAME	BRNCH NO.	RELATIONSHIP TO SPONSOR: Self	
PATIENT'S IDENTIFICATION: (For typed or written entries, give: Name – last, First, middle; ID No or SSN; Sex; Date of Birth; Rank/Grade.)		REGISTER NO.	WARD NO.

LN, FN, MI:
SSN:
SEX:
DOB:
RANK:

CHRONOLOGICAL RECORD OF MEDICAL CARE
Medical Record
STANDARD FORM 600 (REV. 6-97)
Prescribed by SECNAVINST
FIRMR (41 CFR) 201-9.202-1

An example of an environmental/occupational health workplace exposure data form completed for a forward deployed location in Iraq.

SUBMISSION OF MANUSCRIPTS TO THE *ARMY MEDICAL DEPARTMENT JOURNAL*

The *United States Army Medical Department Journal* is published quarterly to expand knowledge of domestic and international military medical issues and technological advances; promote collaborative partnerships among the Services, components, Corps, and specialties; convey clinical and health service support information; and provide a professional, high quality, peer reviewed print medium to encourage dialogue concerning health care issues and initiatives.

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