Chapter 22

PERSONAL PROTECTION MEASURES AGAINST ARTHROPODS

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INTRODUCTION

Proper use of a system of personal protection measures (PPMs) can be very effective in preventing disease transmission and reducing nuisance bites by biting or blood-sucking arthropods. The US military's system of PPMs includes the application of insect repellents on skin and field clothing and proper wearing of the field uniform. Operational doctrine supports the use of PPMs whenever the risk of receiving insect bites is significant, including the relatively few instances when vaccines (eg, yellow fever and Japanese encephalitis vaccines) or chemoprophylaxis (eg, anti-malarial pills) are also available to prevent arthropod-borne diseases. A medical threat assessment performed before deployment is essential in defining the risk that insect bites pose to deployed personnel. In addition to PPMs, unit-level preventive medicine and field sanitation teams in each service play a crucial role in vector control. In many tactical field situations involving combat or rapid troop movements, use of PPMs may be the only practical option to prevent arthropod-related casualties. Even in those tactically stable situations where pesticide application may be possible, widespread use of pesticides may be impractical because of the time, personnel, and equipment needed to perform area pesticide application, plus the hazard to the environment and the contribution to increasing vector resistance. Service members must be capable of using and adhering to the US military's system of PPMs when they are at significant risk of becoming arthropod-related casualties (Figure 22-1).

Fig. 22-1. Personal protection measures have protected US forces in the past and their correct usage continues to protect today's service members.
US War Department poster, 1945. From the Letterman Army Institute of Research, Presidio of San Francisco, Calif.

THE ARTHROPOD THREAT

The arthropod threat to a military force includes contact with disease vectors and nuisance factors. Arthropods can inflict severe physiological stress, and their bites can be painfully distracting and lead to devastating secondary infections, dermatitis, and allergic reactions. Arthropods can cause serious erosions in individual and unit performance. A study[1] in the Karelian Republic, Russia, showed that use of an insect repellent (dimethyl phthalate) increased the efficiency of workers in logging camps by 25%. In military terms, this could be the equivalent of several extra battalions in every division. The diseases transmitted by insects are equally important. Four of the most important parasitic diseases of humans are arthropod-borne. Of the 80 diseases important to military operations, more than two thirds are transmitted by arthropods.[2] Both individual and unit adherence to PPMs is essential if arthropod-related casualties are to be minimized.

There are many examples that illustrate the detrimental affect of arthropod-borne disease and nonbattle injuries on military campaigns. One of the most striking examples depicts the tremendous losses suffered by Napoleon's army during his campaign of 1812. In June 1812, Napoleon invaded Russia with 422,000 men. In September, the army reached Moscow, but by this time, he had lost seven of every ten soldiers to epidemic louse-borne typhus[3] (Figure 22-2). With the force already reduced by disease, cold injuries on the retreat from Moscow completed the rout. Dysentery and pneumonia together with typhus reduced the Grande Armee further and by June 1813, fewer than 3,000 of the original force were alive.[4]

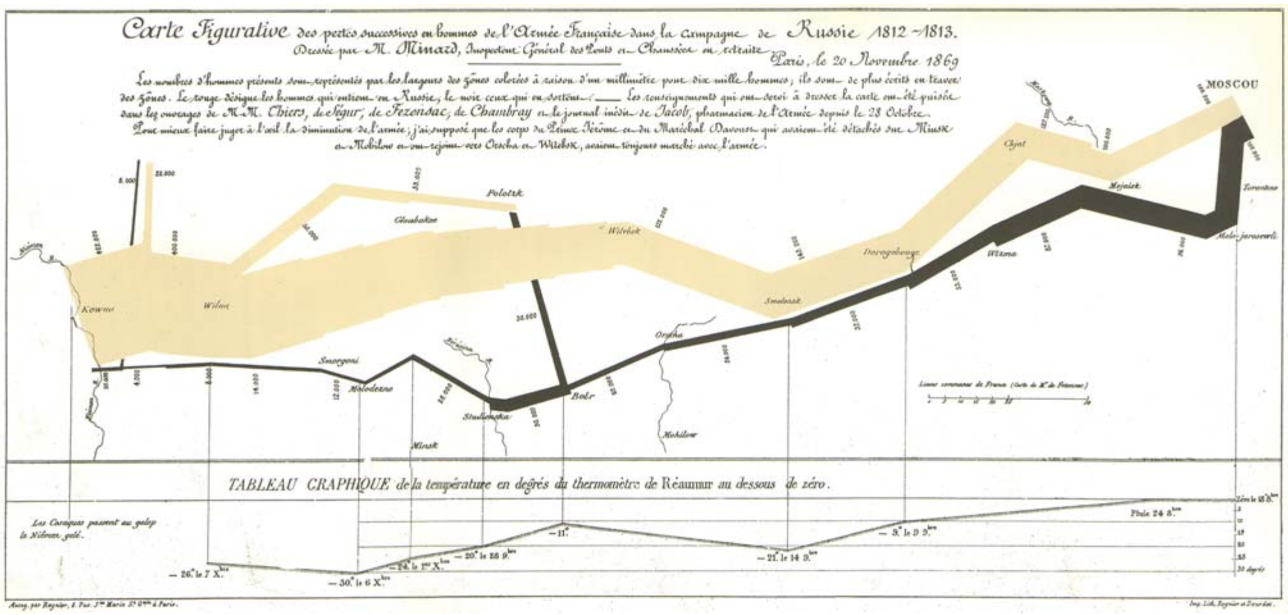

Fig. 22-2. Normally, Napoleon's campaign in Russian in 1812 is given as a classic example of the effects of environmental injury of an army. It is also an example of the effects arthropod-borne disease can have. As described by Robinson* in June 1812, Napoleon invaded Russia entering from the Polish-Russian border near the Nieman River with 422,000 men. The width of the band indicates the size of the army at each place on the map. The movements of auxiliary troops are also shown, as they sought to protect the rear and the flank of the advancing army. The path of Napoleon's retreat from Moscow is depicted by the darker, lower band, which is linked to a temperature scale and dates at the bottom of the chart. Typhus struck down seven in ten of the Grand Armee on its march into Russia. With the force already reduced by disease, cold injuries completed the devastation. It was a particularly cold winter, and many froze to death on the march out of Russia. After a disastrous crossing of the Berezina River, the army finally struggled back to its starting point with only 10,000 men remaining.
* Robinson AH. The thermatic maps of Charles Joseph Minard. *Imago Mundi.* 1967;21:95–108. Map reproduced with permission from Edward R. Tufte. *The Visual Display of Quantitative Information*. Cheshire, Conn: Graphics Press; 1983.

Historically, malaria has been and still remains one of the most serious arthropod-borne disease threats for the US military, particularly the Army, in strategic parts of the world. During World War I, an estimated 2 million man-days were lost to the debilitating effects of malaria.[5] Nearly 695,000 cases occurred during the 4 years the US fought in World War II, with an estimated 12 million man-days lost to the US forces during that period.[6] During the Korean War, US forces reported 390,000 cases of malaria, and during the Vietnam War, more than 50,000 cases occurred among US military personnel.[7] Malaria, as well as dengue fever, has been reported during more recent deployments, such as Operation Restore Hope in Somalia.[8–10]

Future US military operations will continue to expose military personnel to region-specific biting arthropods and the vector-borne diseases they carry. The degree of exposure will largely depend on environmental factors and operational intensity. Success of high-intensity field operations in regions of significant arthropod biting may be associated with service members' adherence to an effective system of PPMs. One lesson to be learned from the medical management of disease casualties from past wars is that the military must prepare during peacetime to meet the emergencies of war.[11]

PROPER AREA CONTROL AND SANITATION

Minimizing the impact of arthropod bites and related diseases in the field begins with proper area control and sanitation. A careful decision regarding where to establish bivouac sites can greatly aid the effectiveness of field sanitation activities. For example, exposure to arthropods can be avoided or reduced if operational field sites and bivouac areas are established on high, well-drained ground away from arthropod habitats and breeding areas.[12] It may be important to clear environments of underbrush that support arthropod-resting sites or animal hosts. Clearing may take the form of raking and cutting grass. If controlled burning is to be used, considerable environmental expertise and planning is essential. Mosquito breeding areas—usually standing water sites or discarded containers such as tires and 55-gallon drums—should be eliminated by draining, filling, or relocating discarded containers where they can be destroyed using methods approved by environmental authorities. Standing water should not be created or allowed around water points, laundry facilities, and other military operations. Area application of pesticides, which must only be done by trained personnel, should be considered by preventive medicine professionals only if other interventions do not achieve the needed level of control. Service members normally should not enter pesticide-treated areas until residual pesticide has completely dried.

Some arthropod species and their animal hosts are attracted to decaying food and waste. Therefore, it is essential that all deployed personnel follow excellent field sanitation practices ("stash your trash") to minimize materials that might attract pests and vermin. Although Army field sanitation teams and their equivalents in the other services play key roles in managing effective area control and field sanitation programs, persistent command emphasis mandating the participation of each individual is vital to unit success.[13,14]

DEPARTMENT OF DEFENSE PERSONAL PROTECTION MEASURES SYSTEM

The most effective personal protection system is a combination of three elements: controlled-release deet (*N*,*N* -diethyl-1,3-methylbenzamide) as a topical repellent, permethrin-treated field uniforms, and proper wearing of the field uniform (Figure 22-3). This system of overlapping protection is necessary because it is usually necessary to defend against several types of biting arthropods simultaneously under changing field conditions and each component of the system has its own limitations. Sand flies and biting midges cannot bite through clothing, so proper wearing of the uniform plus insect repellents will be effective against them. Clothing impregnation with repellents may be necessary to provide protection from mosquitoes, tsetse flies, deer flies, and many other insects that can bite through the field uniform. Ticks and other insects attempt to crawl under clothing; therefore, routine buddy checks may be indicated.

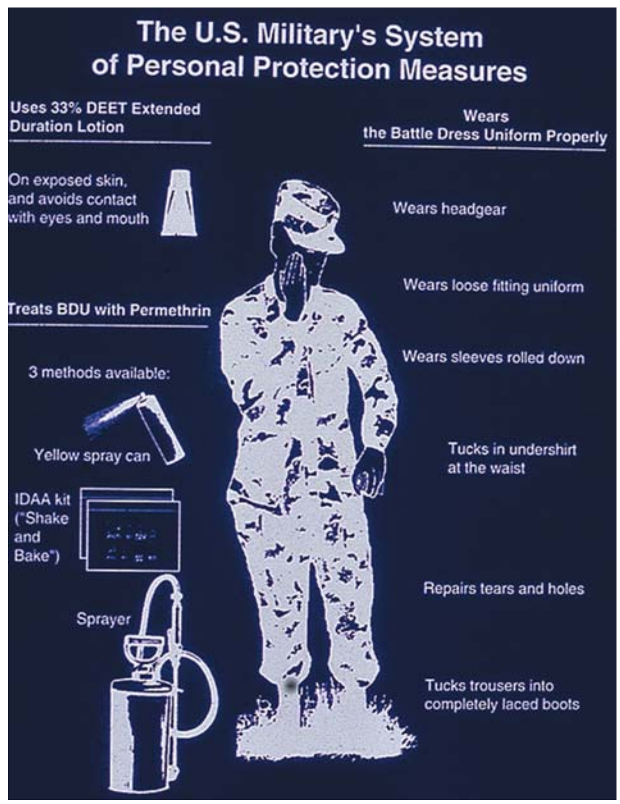

Fig. 22-3. To be most effective, adherence to all three components of the US military's system of personal protection measures is essential.
Graphic courtesy of Kathleen Huycke, Walter Reed Army Institute of Research, Silver Spring, Md.

INSECT REPELLENTS

Along with proper area control and sanitation, use of insect repellents is a vital countermeasure in reducing arthropod-related casualties. Dethier[15] defines a repellent as a chemical that causes the insect to make oriented movement away from its source. Repellents may be classified based on their site of application or their mode of action. The two important types of insect repellents are topical repellents and clothing repellents. Based on the mode of action, insect repellents can be further classified as vapor (or olfactory or spatial) repellents and contact (or gustatory) repellents. Repellents such as deet, dimethyl phthalate, and ethyl hexanediol depend on their vapors to keep insects at a distance,[16] but the contact repellents, such as Indalone, are slightly volatile so that the insect must touch the treated surface before being repelled.[17,18] Permethrin, which functions as a contact repellent and contact insecticide, as well as a short-range olfactory repellent, has largely replaced every other repellent in the military system for use on clothing and other fabric items.

The identity of the first repellents used by humans is lost in prehistory, but they were no doubt similar to those in use as folk remedies today. In the Jeypore and Madras regions of India, women and girls apply turmeric *(Curcuma longa*, Family Zingiberaceae) in vegetable oil daily for protection against mosquitoes.[19] In some areas of Mexico, the women apply anatto *(Bixa orellana*, Bixaceae) in vegetable or animal oil to the men to protect them against mosquitoes and other insects when they go to hunt, fish, or work.[20] The first recorded use of repellents has not been determined, but Pliny (23–79 AD) and Dioscorides (fl. 60 AD) described use of wormwood juice *(Artemisia absinthium,* Compositae) to repel gnats and fleas.[21] Pliny also described use of the leaves and fruits of citron *(Citrus medica,* Rutaceae) to repel insects from stored clothing.[22]

In the early years of the 20th century, an assortment of natural products, both inorganic and botanical, were still being used to repel insects. Sulfur was dusted on skin and clothing to repel chiggers.[23] Application of a 1:10 solution of Epsom salts (hydrated calcium sulfate) was prescribed by the US Army Medical Field Service School in the 1930s to repel mosquitoes.[24] The preeminent botanical materials were pyrethrum *(Chrysanthemum cinerariaefolium,* Compositae) and citronella *(Cymbopogon nardus,* Gramineae). Sulfur, pyrethrum, and citronella are still in use today in some commerical products.[25]

Topical Repellents

Repellents for topical use are available in a wide variety of forms. These include lotions, creams, foams, soaps, aerosols, sticks, and towelettes. In general, formulations containing greater concentrations of active ingredient provide more effective and long-lasting protection. Aesthetic acceptance of the repellent by the user, though, has a major impact on the amount used and the frequency of use of the various products.

The first synthetic repellents to gain wide acceptance were dimethyl phthalate and dibutyl phthalate, which was patented in 1929.[26] By the end of World War II, dimethyl phthalate, ethyl hexanediol (also called Rutgers 612), and Indalone (butyl-3,3-dihydro-2,2-dimethyl-4-oxo-2H-pyran-6-carboxylate) had been identified as superior mosquito repellents.[27] These were recommended for military use. Dimethyl pthalate is effective against *Anopheles* mosquitoes but less effective against *Aedes* species, whereas the reverse is true with ethyl hexanediol. After the war, combinations of repellents were developed to exploit the respective advantages of these individual components in a single product. The 6-2-2 repellent contained dimethyl phthalate, ethyl hexanediol, and Indalone in the proportion 6:2:2. Dimethyl phthalate and Indalone are still in limited use in 2001, but in 1991 the US Environmental Protection Agency (EPA) canceled all registrations of ethyl hexanediol at the request of its manufacturers because of new information on possible adverse fetal developmental effects.[28]

Deet

Perhaps the single most important event in the evolution of repellents was the discovery of deet in 1954.[29] It has virtually eclipsed other repellents for topical use, and it remains the principal repellent in use today, more than 40 years after its discovery. Deet was initially marketed commercially in 1956, and 75% deet in alcohol was adopted as the standard topical and clothing repellent by the US military in 1957[30] (Figure 22-4). Even though deet is an effective repellent against a broad spectrum of arthropods, it has several drawbacks. Under warm, humid conditions, the application lasts for only 1 to 2 hours. It is a strong plasticizer, has a disagreeable odor, and feels "oily" to some service members. Results from a survey conducted in 1983 indicated that 62% of more than 1,500 troop respondents thought that the Army needed a better repellent.[31] The Armed Forces Pest Management Board has endorsed development of more effective insect repellents for military use.

In the early 1980s, research at Letterman Army Institute of Research (Presidio, San Francisco, Calif) demonstrated the feasibility of various extended-duration mechanisms to release deet at a predetermined rate that was sufficient to prevent insect bites. Subsequently the US Army Medical Materiel and Acquisition Activity (Fort Detrick, Md) worked with private industry to formulate an effective extended-duration deet repellent for topical application to meet the following operational specifications: (*a*) provide at least 12 hours of protection against a wide variety of arthropods, (*b*) be nonirritating and nonallergenic, (*c*) be odorless at a distance of 10 feet, (*d*) have no objectionable oily

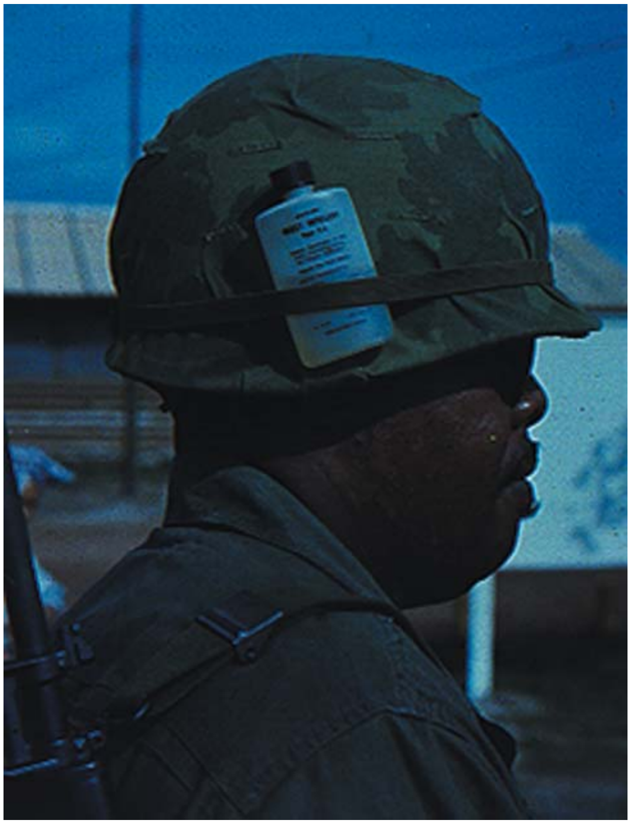

Fig. 22-4. 75% deet in the bottle was the military-issue topical and clothing repellent during the Vietnam Conflict.
Photograph: Courtesy of the Walter Reed Army Institute of Research, Silver Spring, Md.

Fig. 22-5. The standard military insect repellent now in use.
Photograph: Courtesy of the Walter Reed Army Institute of Research, Silver Spring, Md.

appearance or feel on the skin, (*e*) be inert to commonly used plastics, and (*f*) have a shelf life of at least 2 years. Prototype repellent formulations from various manufacturers were tested in a variety of laboratory and field conditions. An extended-duration topical arthropod repellent formulation of deet produced by 3M Company was selected in 1989 as the standard military insect repellent, personal application (NSN 6840-01-284-3982). This multipolymer, extended-duration repellent formulation contains 33% deet and forms a thin film over the surface of skin that slows the absorption and evaporation of deet and provides long-term protection (6 to 14 hours) against a wide variety of militarily relevant arthropods under varying environmental conditions.[32–35]

The extended-duration formulation of deet is the best repellent developed to date (Figure 22-5). It provides long-lasting protection at a much lower percentage of the active ingredient (33%) than past formulations and so is more cosmetically acceptable. Nevertheless, the intrinsic repellency of deet is inadequate against biting midges and black flies and only marginally adequate against some anopheline mosquitoes.

Progress in the development of new repellents has been limited. One important reason for the lack of success in this area is the limited understanding of the repellents' mode of action on the target organisms. The general assumption that all repellents affect all arthropods in the same way is incorrect. It has been shown that even strains of the same species differ significantly in their tolerance to the same repellent. Therefore, selection of appropriate repellents for personal protection greatly depends on the species to be repelled. Also, a certain minimum effective evaporation rate of repellent is required to effectively repel insects.[36] Repellent applied on the skin decays exponentially with time, and evaporation and absorption rates account for a substantial fraction of the loss.[35] In addition, it is believed that abrasion (loss of topical repellent due to mechanical action such as rubbing) plays a significant role in repellent loss from skin. It has been shown that the clothing abrasions of repellent-treated skin affected the efficacy of the extended-duration formulation of deet.[37] An increase in the number of repetitions of skin abrasion by clothing resulted in a reduced duration of protection against mosquito bites. To maximize repellent effectiveness, it is important to test new repellent formulations under the conditions that service members experience in the field.

An active, joint-service research program is directed toward discovering new repellent materials for future use. Efforts have begun at the Walter Reed Army Institute of Research (Silver Spring, Md) to create multipurpose insect repellent formulations, such as sunscreen insect repellent and camouflage face paint repellent combinations, to improve repellent effectiveness, ease of application, and user adherence (Figure 22-6). Recent advances in the delivery mechanisms and formulation of insect repellent with camouflage face paint may increase insect repellent use because camouflage skills are taught as an integral part of basic training. Laboratory[38] and field studies have proven that a camouflage face paint repellent formulation is feasible and effective. An added advantage of this product would be the visible indication that it had been applied to exposed skin.

Montemarano and colleagues[39] have shown that sequential use of sunscreen and insect repellent results in reducing the sun protection factor (SPF) by 28%. A successful sunscreen insect repellent that provides protection against both sun rays and insect bites has shown efficacy under laboratory and field conditions. Moreover, it uses only 20% deet and provides similar protection from insect bites as the extended duration repellent formulation containing 33% deet (R.K.G., unpublished data, 1996).

Deet Side Effects

It is estimated that 50 million to 100 million persons use deet each year, and few cases of adverse reactions have been reported.[40] It has been associated with allergic and toxic effects in some people, especially when used repeatedly on the skin in high concentrations. A report in 1976 showed regular applications of deet on the skin of white rats was gonadotoxic and embryotoxic.[41] Deet is partially absorbed through skin and has been used to enhance transdermal delivery of drugs.[42] In human studies, variable penetration into the skin from 9% to 56% of a topically applied dose and absorption into the circulatory system of approximately 17% has been reported. Urinary excretion of deet, which accounted for most of the absorbed repellent, occurred primarily in the first 24 hours in animal models.[30] Deet has been associated with bullous eruptions in the antecubital fossa and contact urticaria, and rare cases of toxic encephalopathy have occurred with excessive or prolonged use, particu-

a b

Figure 22-6. Field trials of insect repellents are vital to evaluate how the repellents perform under real-world conditions and how the products are perceived by the intended users: military personnel. (**a**) A field trial of three experimental controlled-release topical insect repellents was conducted by the US and Australian militaries at the Joint Tropical Trials Research Establishment, Australian Department of Defense, near Innisfail, Queensland, Australia. Two Australian soldiers are collecting biting insects after applying one of the assigned treatments including test formulations. (**b**) US soldiers are participants in a field study of camouflage-face paint-insect repellent formulations in Panama in 1997.
Photographs: Courtesy of Colonel Raj Gupta, MS, US Army; Walter Reed Army Institute of Research, Silver Spring, Md.

larly in infants and children.[43] To minimize possible adverse reactions to deet, only products containing less than 35% concentrations of deet should be used and the skin should be cleaned as soon as the risk of arthropod biting is over.

Of 9,086 human exposure cases reported to poison control centers involving deet-containing insect repellents, two thirds had no adverse effects or experienced only minor symptoms.[44] The majority of the people exposed to deet-containing repellents went home after an evaluation and therapy in emergency departments. Sixty-six patients had moderate effects, and the majority of these cases had ocular symptoms. Deet generally is of low acute toxicity, and, based on the available toxicological data, the EPA has concluded that the normal use of deet does not present a health concern to the general US population. Deet has been classified as a Group D carcinogen (not classifiable as a human carcinogen). Although deet's use has been implicated in seizures among children, the incident data are insufficient to establish deet as the cause of the reported effects. However, the EPA required improved label warnings and restrictions on all deet product labels.

Clothing Repellents

History

Many repellents can be applied to field clothing for protection against militarily important arthropods, especially those that crawl or hop (eg, mites, ticks, fleas, body lice). Repellents that are or have been widely used for clothing impregnation include sulfur, dimethyl phthalate, dibutyl phthalate, benzyl benzoate, deet, and permethrin. These materials are also effective when applied to bed nets, curtains, window screens, ground cloths, tents, and protective overgarments.

The need for clothing repellents came into prominence during World War II, with the high incidence of scrub typhus in the Pacific Theater. The value of repellent-impregnated clothing was observed when comparing three similarly sized patrols operating in the same area in the South Pacific in 1944. The first and third patrols were not protected by repellent-impregnated clothing. The first had 53 cases of scrub typhus and the third had 23 cases. In contrast, dimethyl phthalate was liberally applied to the clothing and gear of the second patrol. No member of this second group developed disease; two individuals acquired a single mite bite.[45]

The major problem with dimethyl phthalate was that it became ineffective after a single rinsing in cool water. As the war ended, benzyl benzoate was adopted by the US Army as its standard clothing repellent. It was shown to be effective through at least two soap-and-water washings. The US Department of Agriculture continued to search for clothing repellents for military use that were more persistent and more effective against a wider range of species. In 1951, a new mixture of compounds, M-1960, was found and adopted as the standard clothing repellent for the military.[46]

Clothing repellent M-1960 contained 30% 2-butyl-2-ethyl-1,3-propanediol for protection against mosquitoes and biting flies, 30% N-butylacetanilide for ticks, 30% benzyl benzoate for chiggers and fleas, and 10% of an emulsifier, Tween 80 (polyoxyethylene ether of sorbitan monooleate). Clothing treated with M-1960 was proven 100% effective against chiggers and more than 90% effective against mosquitoes, ticks, and fleas, but clothing had to be retreated after each washing. M-1960 repellent was widely used by US forces during the Korean War to reduce mite bites then thought to transmit epidemic hemorrhagic fever. Both M-1960 and benzyl benzoate had a number of undesirable qualities, such as causing skin irritation, having a disagreeable odor, and being a plasticizer; they were poorly accepted by military personnel and are no longer used.

Permethrin

Permethrin (3-phenoxybenzyl(±)-3-(2,2-dichlorovinyl-2,2-dimethylcyclopanecarboxylate) is a synthetic pyrethroid insecticide and repellent first synthesized in England in 1972. Starting in 1977, it was studied by the US Department of Agriculture for the Department of Defense for use as a clothing treatment to protect the wearer from biting arthropods. But in 1983, the Program Manager for Arthropod Repellents, US Army Medical Materiel and Development Activity (Fort Detrick, Md), organized an advanced development program for permethrin that involved the Letterman Army Institute of Research; the US Army Natick Research Development, Test, and Evaluation Center (Natick, Mass); the Walter Reed Army Institute of Research; the Uniformed Services University of the Health Sciences (Bethesda, Md); and the US Department of Agriculture (Gainesville, Fla).

Permethrin has no noticeable odor, is nonirritating, has low mammalian toxicity, is biodegradable, and provides excellent protection against many different species of biting arthropods. Clothing treated at 0.125 mg/cm^2 has excellent permethrin retention in spite of wear and wash abrasion, weathering, and light-induced chemical breakdown. Persistence of permethrin in fabrics far exceeds that of any previously available repellent. A further advantage of permethrin and other pyrethroids is that they act as insecticides as well as repellents.

Eight to ten different methods for permethrin application of field uniforms were investigated and the following methods were found to be economical, efficient, and effective in providing long-term protection against militarily-important arthropods (Figure 22-7). Four impregnation methods were registered for US Army use by the EPA: (1) the Individual Dynamic Absorption (IDA) Application, (2) the 2-gallon sprayer, (3) the aerosol can, and (4) the Pad Roll. A new method of treating finished uniforms has completed user-acceptance trials and will be available for us in the future.

The IDA kit ("shake and bake") contains two small containers of 40% permethrin, treatment bags, twine, disposable gloves, and a marking pen. The kit is designed for use by the individual service member; and one kit treats one field uniform (shirt and pant). The shirt and pant are separately rolled and tied in the middle by twine. Three-quarters of a canteen cup of water is poured into each treatment bag along with contents of one of the containers. The

a b c

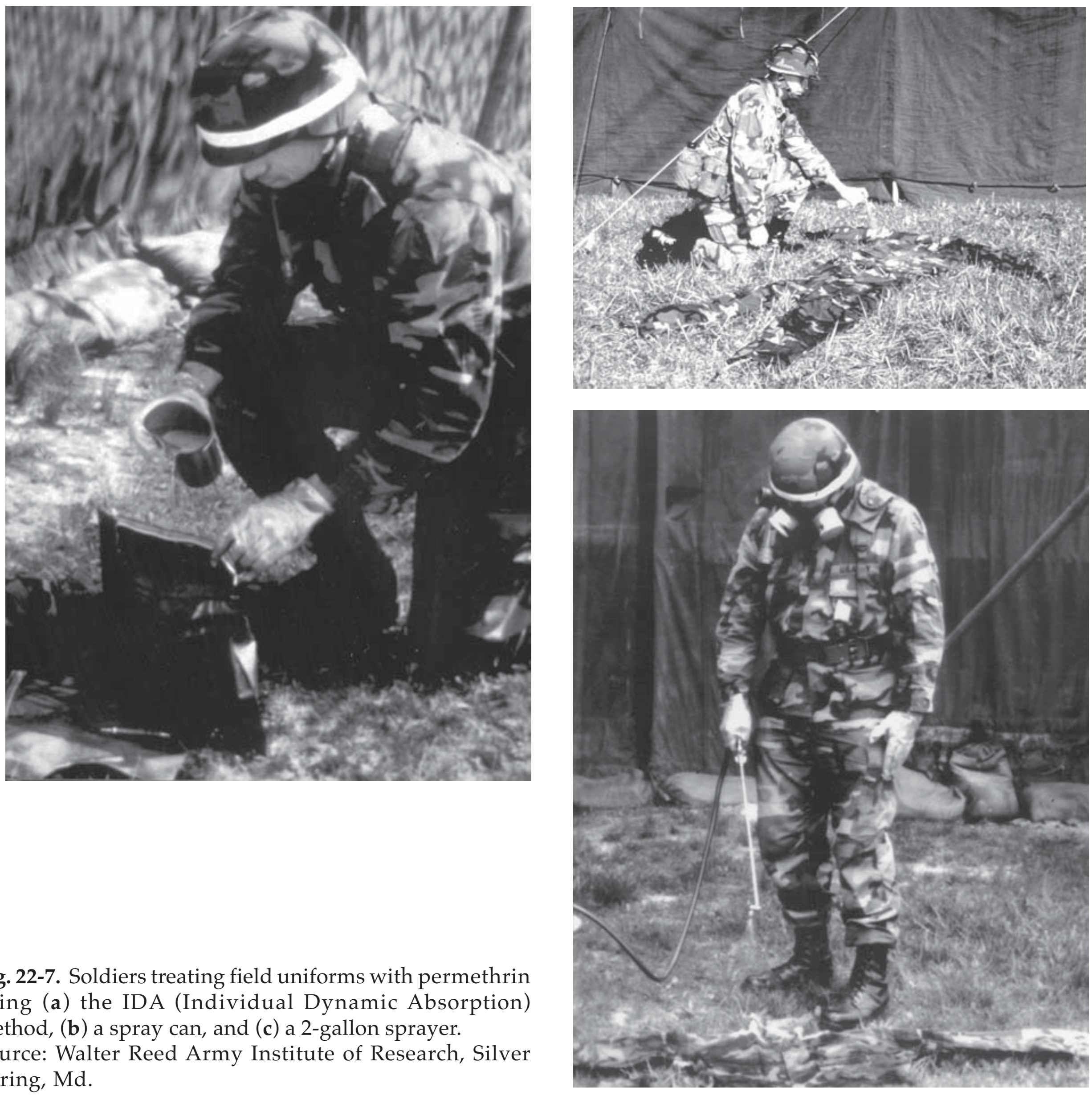

Fig. 22-7. Soldiers treating field uniforms with permethrin using (**a**) the IDA (Individual Dynamic Absorption) method, (**b**) a spray can, and (**c**) a 2-gallon sprayer.
Source: Walter Reed Army Institute of Research, Silver Spring, Md.

bag is shaken to mix the water and permethrin, the rolled shirt or pant is placed inside its own bag, and the fastener is closed. Then the bag is left undisturbed for 2.5 hours while the liquid is being absorbed by the cloth. The shirt or pant is then hung and allowed to dry thoroughly. During field trials, this method was shown to be simple and effective.

The 2-gallon treatment method is used to treat field uniforms and tents. The 40% permethrin from the 5.1-ounce (151 mL) bottle is mixed in a sprayer containing 2 gallons of water, and the sprayer is brought to a pressure of 55 psi. The 2-gallon field sprayer can treat nine sets of field uniforms per 5.1-ounce bottle. The field uniforms are placed flat on the ground and sprayed evenly until all the material is thoroughly wet. They are then hung to dry. Two-gallon compressed air sprayers are required equipment of company-sized Army unit field sanitation teams and are used by all the services. This is a simple and effective method if properly done.

Aerosol spray cans containing 0.5% permethrin may also be used for treatment. The application to the field uniform is made by holding the spray can 6 to 8 inches from the clothing. The uniform is laid flat on the ground and the outer surface is treated. This method is simple but is not as efficient and effective as the other methods.[18,47]

The Pad Roll method for impregnation involves pretreating field uniform cloth during the manufacturing process. The fabric is passed through a permethrin and water bath and is then sent through squeeze rollers. After it is dried, the cloth is then made into uniforms.[48] The last method, factory treatment of finished uniforms, involves treatment of individual uniforms during the manufacturing process.

Permethrin treatment—using the IDA kit, 2-gallon sprayer, Pad Roll application, and factory treatment of finished uniforms methods—provides effective protection against insects for up to 50 washings; the aerosol can method lasts for six washings. Starching field uniforms does not affect the treatment but certain dry cleaning processes may remove it. Underwear and caps should not be treated with permethrin. Tentage should be re-treated after 9 months in temperate climates and after 6 months in tropical climates. Preventive medicine personnel should monitor the level of protection achieved after treatment of clothing.

OTHER PROTECTIVE MEASURES AUTHORIZED FOR MILITARY PERSONNEL

The Uniform

One of the most practical means of reducing arthropod bites that is often overlooked, neglected, or not enforced is the proper wearing of the field uniform. Most insects cannot bite through its material unless it is tightly stretched against the skin. Service members must remember to wear a loosely fitted uniform and minimize the amount of skin exposed to blood-sucking or biting arthropods. Shirts should be worn with collars closed and sleeves rolled down from dusk until dawn or whenever mosquitoes or biting flies are present. The bottom of trousers should be tucked inside the tops of boots, and undershirts should never be worn as the outer garment when the threat of vector-borne disease exists.[48] Service members should shake out all clothes before putting them on, wear socks and shoes whenever walking, and look closely before reaching into concealed areas. Tears or holes in the field uniform should be repaired. Individuals should use a buddy system frequently to check for ticks on body areas that cannot easily be personally surveyed and to remove ticks that are found safely. Protection against insect bites is of paramount importance during off-duty hours when service members may let down their guard and wear shorts, sandals, and t-shirts. Exposed skin should be protected with deet repellent if biting arthropods are present. National Stock Numbers and costs of some of the items mentioned here are listed in Table 22-1.

Head Nets

The head net is a fine-mesh, olive-drab, nylon screen that is designed to fit over headgear (Figure 22-8). The cloth top piece has an elastic suspension that fits over the kevlar helmet or other headgear. Metal rings hold the net away from the face and neck. It is worn over the collar in back and is held in place in the front by two elastic loops that can be attached to the pocket buttons of the shirt. Properly worn head nets will protect against biting insects and are particularly useful in areas where biting flies and mosquitoes are so numerous that they overwhelm repellents, as in the Arctic during summer.[48]

Bed Nets

Bed nets, or insect bars, have long been used to protect people from mosquitoes and sand flies. The bed net is a canopy usually made from finely woven nylon mesh (Figure 22-9). It may be used with the folding cot, steel bed, shelter-half tent, or ham-

TABLE 22-1

NATIONAL STOCK NUMBERS AND COSTS OF SOME PERSONAL PROTECTION ITEMS AVAILABLE THROUGH THE MILITARY SUPPLY SYSTEM AS OF JULY 2000

Item	NSN	Units of Issue	Cost ($)
33% Deet Repellent, Extended Duration	6840-01-284-3982	12 2-oz tubes/box	34.32
0.5% Permethrin, Clothing Application	6840-01-278-1336	12 6-oz cans/box	38.41
40% Permethrin, Clothing Application	6840-01-345-0237	12 IDA kits/box	42.77
2-Gallon Sprayer, Pressure Type	3740-00-641-4719	Each	140.11
40% Permethrin, Clothing Application	6840-01-334-2666	12 151-mL bottles/box	159.30
Pole, Folding Cot, Insect Net Protector	7210-00-267-5641	Set	4.05
Insect Net Protector	7210-00-266-9736	Each	27.20
Insect Bar, Head Net	8415-00-935-3130	Each	5.15
Parka, Insect Repellent, small	8415-01-035-0846	Each	16.60
Parka, Insect Repellent, medium	8415-01-035-0847	Each	16.60
Parka, Insect Repellent, large	8415-01-035-0848	Each	16.60
Jacket, Bug-Out outer wear, small	01-483-2988	Each	37.60
Jacket, Bug-Out outer wear, medium	01-483-3002	Each	37.60
Jacket, Bug-Out outer wear, large	01-483-3004	Each	37.60
Jacket, Bug-Out outer wear, extra large	01-483-3007	Each	37.60
Jacket, Bug-Out outer wear, extra extra large	01-483-3008	Each	42.50

IDA: Individual Dynamic Absorption
Source: Department of Defense Pest Management Materiel List (Other Than Pesticides). May 1, 2001. Maintained by the Armed Forces Pest Management Board, Forest Glen Section, Walter Reed Army Medical Center, Washington, DC 20307-5001.

mock. Poles to help suspend the bed net over the folding cot are available. The net must be suspended so that there is clearance between it and the sleeping person. While bed nets not treated with permethrin performed well, numerous studies[49] indicate that treated bed nets, even those with holes, were far superior to untreated bed nets. Research efforts are underway to develop a bed net that has better air flow and is lightweight, self-supporting, easily collapsible, and impregnated with a quick-acting insecticide. The newer design must also be useable with the military cot and on the bare ground.

The new bed net incorporates a self-supporting, low-profile design; a "no-see-um" polyester mesh with factory impregnated insecticide (permethrin); and an integral support frame with canopy. The bed net can be folded into a flat circular package (12 inches in diameter and weighing approximately 2 lbs) and can be carried in the military rucksack or a civilian backpack. When released, the bed net instantaneously springs into a complete and fully deployed bed net. It has a water resistant floor that is also treated with insecticide. It can be used with a military field folding cot, a field hospital bed, or alone.

Fig. 22-8. The standard-issue head net.
Source: Defense Pest Management Information Analysis Center. *Personal Protective Techniques Against Insects and Other Arthropods of Military Significance*. Washington, DC: Armed Forces Pest Management Board; 2000: 16. AFPMB Technical Memorandum 36.

Other Clothing

An insect repellent parka or overjacket made of wide-mesh polyester-cotton netting is worn over outer clothing after being treated with a full 2-ounce bottle of 75% deet (NSN 6840-00-753-4963). The insect repellent parka, fabric mesh (deet jacket) is available in small, medium, and large sizes (see Table 22-1). The waist length parka with extra long sleeves and hood is stored in a plastic bag when not in use. After being treated with 2 ounces of 75% deet and if properly stored and not washed, the parka should remain effective against mosquitoes, biting midges, and biting flies for about 6 weeks before retreatment is necessary.[50]

a

b

c

Fig. 22-9. Bed nets, especially if properly treated with permethrin, offer additional protection against nuisance and disease-carrying insects. Photograph (**a**) shows a soldier demonstrating the use of a bed net with a standard issue cot. Photograph (**b**) shows a Navy Hospitalman 3rd class in the 1st Medical Battalion Field Hospital in Mogadishu, Somalia in 1993. The patients are all in bed under bed nets. This not only protects them from biting arthropod and the diseases they transmit, but it also keeps those personnel with arthropod-borne diseases from becoming sources of nosocomial infections. Photograph (**c**) shows the new self-supporting, low profile bed net design. It is compatible with standard issue cots and hospital beds.
Photograph sources: (a) Defense Pest Management Information Analysis Center. *Personal Protective Techniques Against Insects and Other Arthropods of Military Significance*. Washington, DC: Armed Forces Pest Management Board; 2000: 18. AFPMB Technical Memorandum 36. (b) DoD Joint Combat Camera Center. *US Forces in Somalia*. CD-ROM. March AFB, Calif: DoD JCCC. Image 189. (c) Colonel Raj Gupta, MS, US Army.

A new, smaller mesh jacket that is durable, effective and does not need to be treated with Deet is being introduced into the military supply system. The new jacket, Bug-Out outer wear, will be available in small, medium, large, extra large, and extra extra large. Both jacket systems may be used by those personnel who remain stationary (eg, sentries, forward observers, combat vehicle drivers).

Area Repellents

Area repellents, also referred to as space repellents, are generally applied to a limited area and are designed to reduce or eliminate arthropod biting in the treated area. Space repellents fill the void between personal topical repellents and large-scale area insecticidal control of arthropod vectors. Area repellents have been available from commercial sources for decades; however, none of the systems tested have proven effective enough for inclusion in the Department of Defense supply system.[51,52] Although not an area repellent, d-phenothrin (NSN 6840-01-412-4634) is an aerosol spray insecticide that can be used to spray inside of enclosed spaces such as bed nets and tents immediately before entry.

USE OF UNAUTHORIZED PRODUCTS BY SERVICE MEMBERS

Although many service members use them to repel arthropods, certain commercial repellents and other products are not authorized for military use. Therefore, commercial repellents, even if they contain deet, are not to be substituted for standard military-issue 33% deet extended-duration lotion or permethrin formulations. Some service members have reported satisfaction using the Avon bath oil Skin-So-Soft during recreation or training. However, Skin-So-Soft has been shown to provide protection against insect bites for at most 30 minutes,[53,54] and its continual application is not practical during military operations. In 1994, another Avon Skin-So-Soft product containing sunscreen (SPF 15) and insect repellent (0.05% oil of citronella) became available. It should never be considered as a substitute for the standard military-issue 33% deet extended-duration lotion. Other items, such as flea and tick collars, have been associated with severe skin damage when used by humans. The use of garlic, sulfur (from matchsticks), diluted turpentine, high doses of B vitamins, talc, vinegar, or the like have not been shown to be effective insect repellents and can be toxic. These items are not to be added to or substituted for military-issue repellents. Questions or concerns regarding military-issue insect repellents or other items that might be used to repel insects should be directed up the chain of command. Written medical permission is required before substitution is authorized. Available for consultation are the Executive Director or the Contingency Liaison Officer of the Armed Forces Pest Management Board (Silver Spring, Md) and the entomology consultants to the three Surgeons General.

ADHERENCE TO THE US MILITARY'S SYSTEM OF PERSONAL PROTECTION MEASURES

Although the current system of PPMs is the most effective ever fielded, outbreaks of arthropod-borne disease continue to occur during field operations when service members do not properly implement PPMs. For example, there were approximately 200 cases of malaria[8,9,55] among US military personnel who served in Somalia during Operation Restore Hope. In addition to dengue virus infections in Somalia,[10] at least 29 dengue virus infections[56] occurred among US military personnel during the initial phase of Operation Uphold Democracy in Haiti. No effective vaccines exist for malaria, dengue, and many other arthropod-borne diseases so their prevention requires consistent use of PPMs and environmental control of insect populations. (In the case of malaria, adherence to an appropriate chemoprophylactic regimen is also required.) Investigations of both outbreaks led predictably to a recommendation that service member adherence to PPMs be enforced more vigorously to prevent additional cases.

Arthropod-borne disease outbreaks also occur during training. Four cases of cutaneous leishmaniasis were identified among 51 US Army Rangers who attended the French Foreign Legion's Jungle Training Course in French Guiana in 1993. Of 34 Rangers who completed a questionnaire, 27 (79%) reported using insect repellent, but the majority preferred to use commercial repellents they had purchased. Among the four cases, one reported not using any repellent and the remaining three reported using commercial repellents exclusively.[57] The costs to the individual Ranger, the unit, and the military appear excessive given the relatively low cost of available prevention measures.[58]

More than 550 US Army soldiers (approximately half in combat arms) who were deployed either to Kuwait (Operation Vigilant Warrior, 1994), Haiti (United Nations Mission in Haiti, 1995), and Bosnia (Operation Joint Endeavor, 1996) participated in a survey regarding their use of PPMs to prevent insect bites. Survey results[59,60] revealed that:

- 41% of respondents reported that they received insect bites either daily or almost daily.
- 69.5% of respondents felt that they had adequate knowledge about the US military's system of PPMs.
- Less than half (40.3%) of respondents were able to identify the current standard US military-issue insect repellent for skin application (33% deet extended-duration lotion), and 35.6% were uncertain. A smaller proportion of respondents (39%) was able to identify permethrin as the contact insecticide for application to the field uniform.
- Regarding insect repellents applied to the skin, 29.2% of respondents reported using commercial repellents exclusively, 33.8% used both military-issue and commercial repellents, while only 9.9% used military-issue repellents exclusively.
- Field uniforms were treated before deployment by only 7.6%.
- 51.5% of respondents felt that their commanders emphasized the use of military-issue insect repellents in general either some but not enough or not at all.

These survey results and related data[61] suggest that in the mid-1990s many service members were relatively unfamiliar with military doctrine regarding PPMs and did not routinely practice it in the field. Although military-issue repellents appeared to have been largely available, approximately half of respondents felt that their commanders did not sufficiently emphasize their use during deployment.

When implemented in 1991, the US military's system of PPMs was known to be a highly effective tool in preventing insect bites. Future missions during war and peace will continue to expose service members to insect bites and related diseases depending on the time of year, geographic location of deployment, and other factors. In some situations, units in the field may be the targets of very intense insect biting activity or bites that transmit disease. As history has shown, infectious diseases, including those transmitted by insect bites, can change the outcome of vital field operations. Military readiness requires an aggressive field preventive medicine capability, including service members' proper use of the US military's system of PPMs.

Data gathered from deployed US Army soldiers suggest that there is a basic lack of knowledge about the system and, not surprisingly, widespread nonadherence to it. No one likes to get bitten by insects, so many service members needlessly spend their own money to purchase commercial insect repellents for use in the field rather than use the standard military-issue repellents, despite their effectiveness. It is likely that these findings are generalizeable to other units in the US military. As with cold-weather or hot-weather injuries, preventable illnesses associated with insect bites must be considered largely command failures. Commanders are responsible for the health of their personnel, including their appropriate use of PPMs to prevent insect bites.

How can adherence to the US military's system of PPMs by service members be increased to acceptable levels? Greater adherence will only occur when service members develop confidence in the effectiveness of the system to significantly reduce insect bites and in their ability to use the system properly under realistic training and operational conditions. To help personnel build sufficient confidence, commanders must have a working knowledge of the system, practice its use in regular unit training for deployment, and strictly enforce its use in the field (with the help of the unit's field sanitation team).[12] More specifically, commanders must provide leadership[59–63] regarding PPMs in the following areas:

- Training and testing their service members at the unit level; common task testing reinforces the importance of the task and assures regular testing to standards.
- Treating bed nets with permethrin before deployment, as is done with field uniforms, when such measures can be expected to add significantly to the prevention of insect bites in the field.
- Requesting that current doctrine about the use of PPMs be included in field manuals, training materials, and other relevant military publications.
- Using knowledgeable personnel (eg, field sanitation teams) in a timely manner to address service members' attitudes, myths, and memories (eg, of 75% deet) that undermine the current system an encourage commercial repellent use, sporadic repellent use, or no repellent use.
- Including PPM doctrine in their unit's standards of operation, budgeting for and pro-

curing adequate supplies of standard military-issue personal protection items (see Table 22-1), and enforcing the system's use in the field during the entire period units are at risk of receiving insect bites.[64]
- Ensuring that each company-sized unit has a fully functional field sanitation team that is responsible for teaching the system of PPMs, monitoring its use among unit members, providing timely feedback regarding adherence to their commander, and coordinating their activity with division or corps preventive medicine assets, as indicated.
- Providing repellent researchers and doctrine developers with information from the field about what works well and what must be improved in the system so it can become even more practical, effective, and user-friendly.[65]

SUMMARY

The US military's system of PPMs has no equal. It is a command responsibility to ensure that every soldier, sailor, airman, and Marine at risk of receiving insect bites or acquiring an arthropod-borne disease in the field uses PPMs properly. As an important part of their knowledge about deployment medicine, unit commanders must lead their service members in countering the significant threats to health posed by biting insects. This is a vital task that is part of training for deployment. Apathy, negligence, or poor adherence can lead to preventable casualties. As British Lieutenant General Sir William J. Slim wrote in his World War II memoirs, "Good doctors are no use without good discipline. More than half the battle against disease is fought not by doctors, but by regimental officers."[66p180]

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