

MALARIA PREVENTION AND CONTROL IN THE UNITED STATES MILITARY

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ABSTRACT • Malaria continues to be a serious threat to deployed military forces in many areas of the World. United States experiences during, and lessons learned from, World War II, Viet Nam, and Somalia have significantly changed the way that military planners, medical and preventive medicine personnel are facing the malaria challenge. Currently, the US military has a powerful arsenal of educational courses and materials, personal protective measures, and malaria surveillance and control techniques in place to fight malaria. These new tools will hopefully reduce malaria morbidity and mortality during military deployments in the future.

KEY WORDS • Malaria - Malaria prevention - Malaria control - Military - Personal protection.

PROPHYLAXIE DU PALUDISME DANS L'ARMEE DES ETATS-UNIS

RESUME • Le paludisme est toujours une crainte importante pour les forces armées déployées dans de nombreuses régions du globe. Les expériences vécues par les Etats-unis, et les leçons qu'ils en ont retiré lors de la Seconde Guerre mondiale, la guerre du Viêt-Nam et celle de Somalie ont modifié de façon significative la manière dont les responsables militaires et les personnels de santé font face à ce défi. Actuellement, les militaires américains disposent d'un arsenal puissant pour combattre le paludisme : éducation sanitaire, mesures individuelles de protection, surveillance du paludisme et mesures de lutte sont autant d'outils qui réduiront la morbidité et la mortalité liées au paludisme dans les déploiements militaires à venir.

MOTS-CLES • Paludisme - Prophylaxie - Lutte antipaludique - Armées - Protection individuelle.

Malaria continues to be a serious threat to deployed military forces in many tropical and subtropical areas worldwide. It is estimated that 2.3 billion people in more than 100 countries or territories (approximately 41 % of the world's population) live in malarious areas. The global incidence of malaria is estimated at 300 to 500 million clinical cases per year, with about 2 million deaths (1). Military personnel are at particularly high risk of acquiring malaria when deployed to endemic areas. In endemic areas, the native population may appear to be healthy; however, they may be carriers of or semi-immune to malaria that they have been exposed to repeatedly since birth. The pathogen is kept at a low level by the host immune system. This smoldering infection can be quickly passed to new, non-immune humans (US Forces) by mosquitoes. US Forces introduced into a tropical area lack immunity to malaria, and if bitten by infected mosquitoes, their body's immune system will not be prepared to prevent the disease from progressing. The result from military personnel becoming ill from malaria includes loss of

manpower, increased burden on the military health support system, and decreased unit morale. All of these factors reduce the commander's ability to execute the directed mission. US military personnel have accounted for more than 90 % of the cases of malaria imported into the United States (2). In addition, two patients died in the United States in 1996 and 1997 after receiving blood donated by two US Army soldiers who had unknowingly contracted malaria overseas (3). Although this blood transfusion error has only occurred a few times in the past three decades, it underscores the importance of malaria prevention and control in the military.

This paper describes the planning, surveillance and control measures used by the United States Military to minimize the effects of malaria during contingency operations. Chemoprophylaxis and experimental vaccines will not be discussed, as another author in a separate paper will discuss these topics.

HISTORICAL IMPACT OF MALARIA ON MILITARY OPERATIONS

Historically, malaria has been an integral part of the mosaic of all military conflicts in tropical areas. Malaria statistics for Allied Forces during World War II provide ample indication of this close association. US Forces suffered greatly from malaria (694,935 cases, 377 deaths, and over 12 million lost duty days) during numerous campaigns in the Mediterranean and Pacific (4). Only the keen understanding

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• *Actes du congrès*

and herculean efforts of individual commanders reduced the staggering malaria rates in Asia. In World War II, when Lieutenant General Sir William Slim assumed command of British troops in Burma in April 1942, the malaria rate was 84 % per year of total troop strength (5). He described his course of action in his memoirs : « Good doctors are of no use without good discipline. More than half the battle against disease is not fought by doctors, but by regimental officers. It is they who see that the daily dose of mepacrine (anti-malarial chemoprophylactic drug used in W.W. II) is taken... if mepacrine was not taken, I sacked the commander. I only had to sack three ; by then the rest had got my meaning. Slowly, but with increasing rapidity, all of us, commanders, doctors, regimental officers, staff officers, and NCOs (non commissioned officers) united in the drive against sickness, results began to appear... malaria in forward units sank lower and lower, until in 1945 the sickness rate for the whole 14th Army was one per thousand per day ». However, mistakes of the past are usually bound to be repeated, as these valuable lessons are rarely learned. Early in the Vietnam conflict, whole infantry battalions were decimated by malaria, even though almost complete protection was readily available through a combination of chemoprophylaxis, repellents, bed nets, and minimizing skin exposure to mosquito bites by proper wearing of the uniform. In addition, the early failures in the Vietnam Conflict to comprehend the difference between *vivax* and *falciparum* malaria and little command emphasis on prevention doubled the number of out-of-count ry evacuations for that disease. All *vivax* patients could have been treated locally and effectively in the theater and returned to duty. It was not until 1968 that only patients with *falciparum* malaria with specific complications were strategically evacuated out of Vietnam. This finally reduced the burden of medical evacuations for malaria by over 50 % (6).

The malaria threat to force readiness that has confronted commanders in the past similarly confronts our forces today. In 1993, over 200 US Marines and soldiers in certain units participating in Operation Restore Hope in Somalia developed malaria (7, 8). Noncompliance with personal protective measures and chemoprophylaxis, coupled with lack of command emphasis, contributed to this largest outbreak of malaria in US military personnel since the Vietnam conflict. The reasons for this outbreak are a complex mixture of incomplete medical intelligence of the malaria threat, lack of command emphasis on personal protective measures, and the complex life cycle of malaria. Medical surveillance revealed that one-half of all malaria and dengue cases during Operation Restore Hope occurred in a single Marine battalion located in the Baardera area. A subsequent investigation of these outbreaks found that the Marine commander did not enforce recommended countermeasures. Fortunately, the ill Marines recovered, and the unit was not involved in any tactical engagements during this weakened condition.

Most of the cases of malaria among soldiers occurred after they deployed back to the United States. This was a result of medical planners failing to realize that *Plasmodium vivax* was endemic in Somalia and the decision to not provide terminal primaquine prophylaxis. As a result of this decision, resulting

from poor medical intelligence, over 70 soldiers contracted malaria after they quit taking mefloquin after redeployment. This is anecdotal evidence that proper personal protective measures were not followed and mefloquin chemoprophylaxis only suppressed the malaria infection until it was terminated.

PROGRESS TOWARDS BETTER MILITARY MEDICAL PLANNING AND MEDICAL INTELLIGENCE PREPARATION

Medical plans.

The medical planning process is an important part of overall mission analysis and the Commander's estimate in preventing malaria. The planning sequence is a series of deliberate steps representing a logical progression of command and staff actions required to develop plans. This is a continual process ; as new information becomes available or as events occur, the plan is reviewed and updated accordingly. Coordination is one of the most essential elements in successful planning. Preventive medicine personnel coordinate with various staff elements to ensure that the preventive medicine estimate is realistic, supports the commander's overall plan, and can be supported. This estimate process is a doctrinally approved framework used to logically consider all elements employed in combating the medical threat of malaria.

The preventive medicine estimate is an important part of intelligence preparation of the battlefield. This includes considering medical intelligence, endemic disease threats, a map study, health of the command, and available resources. This is always completed within the framework of the commander's guidance, the tactical plan, distribution of units, and support requirements. The preventive medicine plan, as part of the overall health service support plan, is then communicated to the commander.

Failure in the planning process will result in commanders, their staffs, and subordinate units finding themselves unprepared to function in military operations. In the case of malaria prevention, this failure could result in increased numbers of malaria cases, hospital admissions, consumption of valuable medical resources, increased burden on units, and ultimately, mission failure.

Medical intelligence.

Medical intelligence is that intelligence produced from the collection, evaluation, and analysis of information concerning the medical aspects of foreign areas that have immediate or potential impact on policies, plans, and operations (9). Knowledge of endemic and epidemic diseases, and public health standards are an important part of medical intelligence. At the strategic level, the objective of medical intelligence is to contribute to the formulation of national and international malaria policies.

United States medical plans, medical intelligence and preventive medicine personnel now better understand the medical threat that global militaries face and therefore can more effectively prevent, diagnose, and manage those

diseases that effect worldwide readiness and deployability. Medical threat is defined as «a collective term used to designate all potential or continuing enemy actions and environmental situations that could adversely affect the combat effectiveness of friendly forces, to include wounds, injuries, or sickness incurred while engaged in military operations» (10). Few military personnel are aware of the magnitude of the medical threat posed by arthropod-borne diseases, especially malaria. Health service support planners and personnel operating in malarious areas must be aware of the total worldwide threat, as well as the specific threats in areas of planned and potential operations.

Medical planners identify the intelligence requirement and provide that request to the supporting intelligence element within the command. The Armed Forces Medical Intelligence Center (AFMIC), Frederick, Maryland, continually compiles, analyzes, and distributes specific regional vector-borne disease threat information thru military command and medical channels. The AFMIC also provides Medical Capabilities Studies, Disease Occurrence - Worldwide Reports, Foreign Medical Materiel Studies, the Disease and Environmental Alert Report, the Foreign Medical Facilities Handbook, Scientific and Threat Intelligence Studies, Foreign Medical Materiel Exploitation Reports, Quick Reaction Responses, the AFMIC Wire, and Medical Environmental Disease Intelligence and Countermeasures CD-ROM (MEDIC). The MEDIC is particularly valuable for medical personnel as it provides worldwide disease and environmental health risks hyperlinked to Joint Service approved country-specific countermeasure recommendations and other pertinent military medical references. Particularly beneficial to preventive medicine personnel are arthropod vector information, and an expanded section on poisonous and injurious animals and plants, and significant portions of Benenson's Control of Communicable Diseases Manual (11).

Increased emphasis has been placed on medical intelligence and preventive medicine countermeasures to include medical intelligence preparation of the battlefield, environmental health surveillance, field sanitation, and disease surveillance and reporting. The most important tasks for preventive medicine personnel are to ensure that commanders are sensitive to and fully aware of the health threats to deployed troops and to provide an effective tool to rapidly brief the chain of command. This is necessary so that the chain of command can be proactive in meeting sanitation and vector-control requirements.

Medical information.

The US Department of Defense has recently placed increased emphasis on all aspects of deployment environmental surveillance, to include surveillance and prevention of vector-borne diseases. Worldwide specific malaria threat information can now be accessed from both military and non-military electronic and traditional sources. The Armed Forces Pest Management Board (AFPMB), Forest Glen, Maryland, through its Defense Pest Management Information Analysis Center, provides country-specific and regional Disease Vector

Ecology Profiles (DVEPs), the Contingency Pest Management Pocket Guide, and Technical Information Memorandums. In addition, the AFPMB's Contingency Liaison Officer has the full time mission of addressing contingency needs, and will immediately respond to requests for pest management and disease control information or assistance in planning.

The US Navy prepares Vector Risk Assessment Profiles (VECTRAPs), which are concise, current summaries of practical information on vector ecology and disease incidence in specific countries. These are available as hard copy or on computer disk from the Navy Environmental Health Center, Norfolk, Virginia.

The Joint Center for Lessons Learned provides Joint Universal Lessons Learned (JULLS) related to preventive medicine. These are extremely helpful to medical planners and preventive medicine in preparing for contingency operations. The obvious goal of JULLS is to prevent making the same mistakes that have occurred during previous operations.

PREVENTIVE MEDICINE TRAINING

Preventive medicine training in malaria surveillance and control.

Effective malaria surveillance and control during military operations starts with the comprehensive training of all personnel involved with military preventive medicine. These include commissioned officers (preventive medicine physicians, entomologists, environmental science/public health officers, environmental engineers and community health nurses), preventive medicine noncommissioned officers (NCOs) and enlisted personnel (preventive medicine technicians). Training begins with entry-level military and specialty-specific training and continues throughout the military career.

Specialty courses in principles of military preventive medicine, tropical medicine, pest management, and operational entomology, to mention a few, are redesigned to provide preventive medicine personnel with an in-depth knowledge of preventive medicine to include surveillance and prevention of vector-borne diseases. These courses are designed to provide military personnel with the appropriate tools to think clearly, make sound judgments, and make good staff decisions and recommendations to maximize force health protection measures to accomplish the mission.

MALARIA PREVENTION

Personal protection measures.

The most effective and obvious means of preventing exposure to disease-transmitting insects is to avoid their known habitats. However, absolute avoidance of insect pests is often neither practical nor possible. If the tactical situation allows, commanders should choose bivouac sites that are dry, open, and as uncluttered as possible.

Malaria prevention is much more cost effective than treatment. Personnel applying common sense and basic measures to protect themselves can reduce their susceptibility to this disease. The front line of malaria prevention during deployments is the individual service member. The measures used by an individual to prevent arthropod bites are referred to as personal protection measures (PPMs). Personnel applying basic PPMs can reduce their susceptibility to many diseases, including malaria. The PPMs include the proper wearing of the uniform, use of arthropod (insect) repellents, insect netting, aerosol sprays, prophylaxis, and periodic self and buddy checks for the presence of arthropods on the body (such as ticks, lice, and fleas) (12).

Clothing is the first direct line of personal defense against arthropods. Proper wearing of the battle dress uniform (BDU) is essential to minimize skin exposure (12). The pant leg is tucked into the boot with the blouse sleeves rolled down and collar buttoned to help protect the arms and neck from biting insects. It is difficult for attacking pests to bite through the BDU fabric unless it is pulled tightly against the skin. Therefore, the BDU is worn loosely, with an undershirt worn underneath the shirt to act as an additional barrier. The undershirt is tucked into the pants to decrease access of crawling arthropods to the skin. The field cap and its brim help protect the head and face. A head net (30-mesh/inch) can be used over the cap or helmet in areas heavily infested with flying insects. If the risk of heat stress is a factor in a particular environment, common sense and advice from medical or preventive medicine personnel should dictate when uniform modifications are recommended to the commander.

Indoor protection can be greatly enhanced by using bed nets and tent screens. Unlike head nets, the mesh size (27 mesh/inch) of bed netting and tent screens is not fine enough to keep out all biting arthropods, especially biting midges and sand flies. Bed nets and tent screens can be lightly sprayed

with permethrin aerosol for added protection. Treating bed nets and tent screens with repellents significantly reduces the ability of flying arthropods to gain entry.

Department of Defense insect repellent system.

The Department of Defense (DoD) developed the current system of personal protection measures in 1990, at a cost of over US\$ 4 million (13). The DoD insect repellent system includes the proper wearing of the uniform, the application of extended-duration deet lotion to exposed skin, and the application of permethrin to the BDU (Fig. 1). When used properly, the specific elements of the DoD insect repellent system (Table 1) will provide nearly complete protection from arthropod-borne diseases, including malaria.

Since 1957, the US military has used deet (N,N-diethyl-m-toluamide or N,N-diethyl-3-methylbenzamide) as its standard skin repellent (14). Deet is effective against a wide variety of arthropod species, especially mosquitoes and other biting flies. Deet has been used worldwide for over 30 years with an excellent safety record (15). Although it has an excellent safety record, there have been sporadic reports of harmful effects associated with improper use, such as swallowing, spraying into the eye or applying to already irritated skin. A few rare cases of toxic encephalopathy (inflammation of the brain) have been reported from overuse on children.

The DoD in collaboration with the 3M™ Corporation developed the current military deet insect repellent formulation. The product contains 33 % deet in a controlled-release polymer base, and is a nongreasy, white lotion with a mild, pleasant odor. The polymer in the formulation slows the absorption and evaporation of deet, thereby holding it on the surface of the skin for an extended period of time. Laboratory and field testing shows that the extended-duration deet lotion provides up to 95 % protection for up to 12 hours under most conditions.



Figure 1 - Department of Defense Insect Repellent System (used with permission of Armed Forces Pest Management Board).

Table 1. Repellents and personal protective clothing and equipment available through US military supply system.

Item	Intended Use	Units of Issue	Cost US\$
Insect Repellent, Personal Application, 3M™	Protect exposed skin from biting insects	(12) 2-oz tubes/box	34.32
Repellent, Personal, 33 % Deet Stick (Cutter™ Insect Repellent Stick)	Primary use in aviator survival kits	(12) 1-oz sticks/box	30.82
Combination 20 % Deet Insect Repellent and SPF-8 Sunscreen	Protect exposed skin from biting insects and UV sun rays	(12) 0.75-oz tubes/box	1.42
Repellent, Clothing Application, 75 % Deet, 25 % Ethanol	For use only for pretreatment of repellent parka	2-oz bottle	1.47
Insect Repellent, Clothing, Aerosol, 0.5 % Permethrin	Clothing impregnant - Apply to clothing while not being worn	(12) 6-oz spray cans/box	38.41
Insect Repellent, Clothing Application, 40 % Permethrin, IDA Kit	Clothing impregnant - One kit will treat one BDU uniform	12 kits/box	42.77
Insect Repellent, Clothing Application, 40 % Permethrin, Liquid, for 2-gallon sprayer	Clothing impregnant - For use in 2-gallon sprayer for treatment of BDUs	(12) 151-ml bottles/box	159.30
Insect Head Net	Used to protect head and neck from mosquitoes	each	5.40
Insect Net Protector	Used to protect personnel from insects while sleeping	each	26.20
Pole, Folding Cot, Insect Net Protector	Used to suspend Insect Net protector (listed above) from military cots.	set of 4	4.05
Parka, Fabric Vest, Insect Repellent	Used to protect personnel from biting insects	each	16.60
Insect Net, Hat, Nylon Netting	Elastic headwear attachment to protect head and face	each	0.35
Permethrin-treated Desert BDU	Protects deployed forces from biting insects and insect-borne diseases	blouse and trouser set	55.60
Permethrin-treated Temperate BDU	Protects deployed forces from biting insects and insect-borne diseases	blouse and trouser set	54.55
Permethrin-treated Enhanced Hot Weather BDU	Protects deployed forces from biting insects and insect-borne diseases	blouse and trouser set	53.45
Insecticide, 2 % d-Phenothrin	Space spray for indoor use only	12-oz spray can	4.06

Permethrin [(3-phenoxyphenyl) methyl (+/-) cis/trans 3-(2,2-dichloroethenyl) 2,2-dimethyl-cyclopropanecarboxylate] is the most recent addition to the arsenal of personal protective repellents and the most effective clothing impregnate available (12). Its primary mode of action is toxicity; however, it also acts as a contact repellent against mosquitoes and biting flies (15). It is odorless, non-irritating, and resistant to washing and rubbing off (16). Permethrin is bound so tightly to fabric that detergent and water have little effect to remove it. A protective amount of permethrin remains in a treated uniform through multiple launderings. Treated uniforms will continue to provide contact repellency even after many washings, even though they may no longer be toxic to insects (17).

Three different permethrin formulations are available in the military supply system to treat uniforms. Permethrin is only used to treat the shirt and trousers. The cap, underwear, and T-shirt are not treated due to the possibility of skin absorption. The first method, the Individual Dynamic Absorption (IDA) kit is a protective treatment kit that is intended for use by the individual. The IDA kit is sometimes referred to by the nicknames «baggie method» or «shake and bake». The kit contains materials sufficient to treat one complete uniform (shirt and trousers): two plastic vials of permethrin (40 % emulsifiable concentrate, 9-ml each), two plastic treatment bags, two pieces of twine, one pair of disposable protective gloves, and one black marking pen. The uniform shirt and trousers are treated separately. The permethrin is mixed with water in the separate bags and the uniform parts placed into

the bags for approximately 3 hours. The garments are then removed from the bags and allowed to dry (usually 2-4 hours) before wearing. The uniforms are impregnated with permethrin at a rate of 0.125 mg/cm². One treatment is good for the service life of the uniform (approximately 12-24 months).

The second method, the aerosol spray (Insect Repellent, Clothing Application, Aerosol, Permethrin Arthropod Repellent) contains 0.5 % permethrin in a 6-ounce can. It is intended for use by the individual to treat field uniforms, as well as the head net and mosquito netting (bed net and tent screens). This aerosol formulation is also available commercially in the US under such trade names as Permanone™ Tick Repellent, Coulston's Permethrin™ Tick Repellent, Coulston's Duranon™ Tick Repellent, and Coulston's Permethrin™ Arthropod Repellent. The uniform is placed on the ground and the fabric is sprayed for a minimum of 30 seconds on each side. Re-treatment should be made after 6 weeks or the sixth laundering.

The third method is intended for use at the unit level by field sanitation teams. This product (Insect Repellent, Clothing Application, Permethrin, 40-Percent Liquid, 2-Gallon Sprayer) comes in a 151-ml bottle and is 40 % permethrin liquid. The contents of the bottle are added to 2 gallons of water in a 2-gallon sprayer. The material to be treated (uniforms, mosquito bed nets, or inner surface of canvas tents) is placed on the ground and sprayed until the fabric is very wet (approximately 50 seconds on each side for uniforms). One bottle of this permethrin formulation is enough to treat 8 complete uniforms with permethrin at a

rate of 0.125 mg/cm². Re-treatment should not be necessary, as one treatment provides protection from insect bites for the life of the uniform in normal situations. However, re-treatment may be directed by medical personnel after 10 washings if bites by biting flies or mosquitoes begin to occur. After treatment, the uniforms should be hung up until dry (usually 2-4 hours) regardless of the permethrin treatment method used.

Factory permethrin treatment of field uniforms is now available for deploying forces. Uniforms are factory impregnated with permethrin at a dose of 0.125 mg/cm² of fabric. This treatment is projected to last the service life of the uniform. The treated uniforms carry a yellow sew-in label, which denotes that the uniform has been factory treated with permethrin. These uniforms are issued for use by deploying soldiers for areas with a high threat of vector-borne diseases. These uniforms are recommended for malaria and leishmaniasis endemic areas that soldiers will occupy over a period of at least 1-2 months.

A double blind, randomized study in Columbia demonstrated that permethrin-impregnated uniforms can reduce the rates of malaria and leishmaniasis in military personnel by 79 % and 75 %, respectively (18). This was the first determination of the efficacy of permethrin-impregnated uniforms during normal duties in regions of high endemicity of vector-borne diseases. These same permethrin-impregnated uniforms caused a very low incidence (0.9 %) of transient skin irritation among soldiers, thus indicating that these treated uniforms are a clinically safe product.

The use of permethrin-impregnated clothing is comparable in efficacy to other personal protective measures, such as repellents and chemoprophylaxis (18) and is cheaper. Although, chemoprophylaxis with mefloquine or doxycycline is probably > 90 % effective, soldier compliance with taking the drugs remains a problem (18). Permethrin-impregnation of clothing is inexpensive and administratively simple. One IDA kit, which is sufficient to impregnate one uniform, costs US\$5.22, one permethrin aerosol can costs US\$ 3.42 and treats 1 and one-quarter uniforms (US\$ 2.73 per uniform), and one 151 ml bottle of 40 % permethrin liquid, which is enough to treat 8 uniforms, costs US\$ 16.14 per bottle (US\$ 2.02 per uniform). Anecdotal evidence and the personal experience of the author suggest that most soldiers prefer the 6-oz aerosol can due to its ease of use and convenience.

Soldier knowledge and acceptance of personal protection measures.

Recent surveys of US Army soldiers' knowledge, attitudes, and practices regarding personal protection measures to prevent arthropod-related diseases and nuisance bites revealed that more education about PPMs is needed (19, 20). Soldiers have poor knowledge of US military doctrine regarding PPMs and still prefer to use commercial repellent. In 1998, less than one-third correctly identified the military-issue repellents to be used on the skin (32 %) or clothing (26 %). More than one-half (58 %) thought that commercial products were better than military-issue repellents. It is not

surprising that many service members are attracted to non-military products, given personal experience before military service, the abundance of commercial and homemade products, and extensive commercial marketing. However, 74 % admitted that they had not received enough information about the US military's system of PPMs (20). This is supported by the fact that command enforcement of PPMs is historically low.

Commercial repellent products are unauthorized for military use. The US military's system of PPMs is viewed as a package, therefore commercial products, even though they may contain DEET, are not to be substituted for the military-issue extended duration 33 % DEET lotion or permethrin formulations. Although some soldiers have reported satisfaction using the bath oil Avon Skin-So-Soft™, this formulation has only been shown to provide protection against insect bites for at most 30 minutes (13). Other items, such as flea and tick collars, have been associated with severe skin damage when used by humans. The use of home remedies such as sulfur, garlic, or similar items, have not been shown to be effective insect repellents.

Soldier education including PPMs is now included as a common part of predeployment health briefings. In addition, during large deployments (e.g., Somalia, Bosnia, Haiti, and Kosovo), each soldier is given a written «soldier's guide to staying healthy» which describes PPMs in detail. The unpredictability of military contingencies demands that service members be fully capable of properly employing PPMs. No other countermeasures (e.g., vaccines, chemoprophylaxis) can be applied as effectively as PPMs to minimize arthropod-related casualties among non-immune military personnel.

Role of unit leaders.

Malaria prevention and control is a command responsibility. Medical personnel must identify the threats and present effective countermeasures and their benefits in order for commanders to make effective decisions. The complexity of modern military operations coupled with the mobility and dispersion of forces increases the need for soldiers and their leaders to apply PPMs to protect them against malaria. The diligent application of basic PPMs can reduce, and in some instances, eliminate the incidence of disease resulting from the medical threat. Commanders and leaders adequately planning for and emphasizing the use of PPMs can achieve mission objectives by quickly and efficiently executing the mission with healthy and fit soldiers.

Unit leaders reduce the incidence of disease in their command by staying informed of the medical threat. They educate, motivate, train, and equip subordinates during all phases of predeployment, deployment and redeployment to counter the medical threat. Commanders and unit leaders work closely with preventive medicine personnel to emphasize the use of PPMs within their unit to defeat the medical threat.

Unit leaders also reduce unit exposure during peak mosquito biting times (dusk until dawn for most anophelines). This is accomplished by restricting showers and

baths to hours when mosquitoes are not biting, rescheduling of work parties and unit formations, and the proper allocation of screening material to buildings that protect the largest number of personnel during peak mosquito biting times.

UNIT PROTECTIVE MEASURES

Base camp selection.

If the tactical situation permits, base camps are always located in areas where there is a low risk of exposure to infected mosquitoes. The following factors are always considered: presence of mosquito breeding sites; direction of prevailing winds; proximity to settlements with malaria-infected inhabitants; and length of time the unit will be present in the area.

Army field sanitation team.

All Army units of company size or larger are required to have a field sanitation team (FST). The FST aids the unit commander in protecting the health of the command by advising and assisting the commander in the many duties essential to reducing disease non-battle injuries. The FST ensures that appropriate field sanitation facilities are established and maintained, that effective sanitary and control measures are applied, and effective preventive medicine measures are practiced. The FST is responsible for those preventive medicine measures that affect units as a whole or are beyond the resources of the individual soldier (21). This is a critical responsibility because unit effectiveness is greatly dependent upon the health of its soldiers.

The forerunner of the present FST was established during World War II. Commanders were required to appoint malaria control details when the control of malaria and other arthropod-borne diseases was beyond the capability of existing engineer and medical units. In 1956, the operation of these details was expanded to include control of all animal pests. Because of the health problems encountered in 1958 by the American Task Force in Lebanon, the duties of the vector control detail were expanded and the FST was created (21). These duties now include control of animal vectors, field water supply, food service sanitation, waste disposal, and personal hygiene. The unit commander requests assistance from supporting preventive medicine elements when the problems encountered are beyond the capabilities of the FST.

Field sanitation team members are selected by the unit commander. The team must consist of at least two soldiers; one must be a noncommissioned officer. Combat medics constitute the FST in units having organic medical personnel. Soldiers from any specialty can serve on the FST in units without organic medical personnel. Field sanitation team training consists of a 20-hour course conducted under field conditions. Each unit FST is required to keep a limited amount of field sanitation supplies on hand and ready for deployment.

Preventive medicine assets in the theater of operations.

History strongly suggests that substantial sickness will occur among the armed forces when deployment of preventive medicine support is delayed (11). Breakdowns in sanitation can occur while troops are still in mobilization and debarkation assembly areas. These breakdowns in sanitation will appear as increased cases of diarrhea, arthropod-borne diseases, or other illnesses. Preventive medicine personnel are always considered during the initial operational planning and are part of advance party site surveys.

Preventive medicine personnel are an integral part of every step of deployments. They are consulted while preparing for mobilization, employed in mobilization assembly areas, deployed with the first forces entering the theater, employed at locations throughout the theater during deployment, and redeployed with the last units and personnel exiting the theater. This ensures continued and seamless preventive medicine support to provide maximum force health protection.

The preventive medicine staffs of separate brigades, armored cavalry regiments, special forces units, a rear support medical battalions and divisions all have a similar mission. This mission includes identifying the medical threat, prepare essential preventive medicine information for inclusion in operation plans and orders, and medical threat briefings, perform sanitary inspections, monitor disease occurrence, provide limited pest management, monitor field water supplies, and collect environmental samples.

At the Corps level and echelons above corps, preventive medicine detachments provide preemptive, threat-based support to units on an area basis. These detachments consist of two types: entomology and sanitation. They provide preventive medicine support and consultation to minimize the effects of occupational hazards, enteric diseases, arthropod-, food-, and waterborne diseases, and other medical threats to include field sanitation and hygiene, sanitary engineering, diseases surveillance, occupational health, health promotion, pest management, and limited ground pesticide spraying. The entomology detachment has the additional mission of ground and aerial ultra-low volume insecticide spraying for nuisance reduction and vector-borne disease suppression. Many of the preventive medicine detachment tasks are implied and not clearly stated in any plans. This is the most important reason why comprehensive preventive medicine training is critical to mission success.

Each detachment consists of two officers, four non-commissioned officers and five enlisted soldiers. The detachment may function as a single operational unit or may split into a headquarters section and two teams to provide support to a greater number of units. This split-based operations system is normal during large deployments. This system allows for better preventive medicine coverage and quicker response to the needs of commanders and soldiers. The detachment or teams collocates with the supported unit. Attachment and direct support missions are usually for limited periods of time. Therefore, the detachment relocates frequently as problems are resolved and the medical threat

changes. The detachment works under a centralized command and control system, but under a decentralized system for mission execution.

During large contingency operations, the Theater Army Medical Laboratory (TAML) can be deployed into the theater of operations to provide state-of-the-art laboratory capabilities. These include providing rapid diagnostic capabilities for select infectious diseases (i.e., malaria, dengue, hantavirus) and an expanded array of environmental monitoring and epidemiological support.

Preventive medicine assets outside the theater of operations.

Field commanders can request a vast array of preventive medicine assets outside the theater of operations, if needed. These assets, located both inside and outside the continental US, include highly specialized preventive medicine teams from the US Army Center for Health Promotion and Preventive Medicine (USACHPPM), US Navy Disease Vector Ecology and Control Centers (DVECC) or US Navy Environmental and Preventive Medicine Units. These specialized teams of experts are worldwide deployable on short notice to accomplish a wide variety of missions to include rapid vector-borne disease surveillance and threat assessments, environmental health surveillance, and epidemiological investigations.

The US Air Force has modified C-130A fixed wing aircraft for large-scale aerial spray delivery of ultra-low volume pesticides in case of vector-borne disease outbreaks or epidemics. This method is usually requested when the area to be sprayed is greater than 5,000 acres.

The AFPMB has a wide array of personnel and information to assist deployed preventive medicine personnel. These include information analysts who assess the threat of vector-borne diseases, military and civilian entomologists with expert knowledge and experience in vector surveillance and control, research scientists who study specific vectors and diseases, and supply logisticians who aid in the procurement of necessary pesticides and equipment. The AFPMB publishes the «Contingency Pest Management Pocket Guide» to provide basic information on using pesticides to control insects that transmit disease. In addition, the AFPMB publishes the list of «DoD-approved Contingency Pesticides». The purpose of this list is to provide basic information on pesticides approved by the AFPMB Contingency Advisory Group for control of disease vectors and pests during field operations worldwide.

Malaria vector control methods.

The objective of any intervention is the prevention and reduction of malaria morbidity and mortality via transmission control. Therefore, the monitoring of this outcome is an essential part of malaria control. Experience has shown that a thorough understanding of the malaria problem and risk and knowledge of the vector, the human host and the environment are prerequisites for effective planning and targeting of vector control interventions (22). Analysis of this information

permits for critical comparisons between different interventions prior to use and the implementation of the most effective vector control methods.

Vector control is an essential component of malaria control during contingencies. Vector control includes two stages: surveillance and control. Preventive medicine teams deployed in contingency operations are prepared to survey base camps for mosquitoes and other vectors, determine their breeding sites, and establish programs to control them. Mosquito surveillance and analysis of collected data leads to choice of control measures most applicable to the area and situation. These preventive medicine teams include medical entomologists who are experienced at implementing public health measures and providing technical guidance to commanders and unit personnel.

Larval mosquito surveys are accomplished to identify breeding habitats, and later to evaluate control measures. Preventive medicine personnel check all possible breeding sites by sampling a uniform volume of water, and counting and identifying larvae present. The larval index is then calculated (average number of larvae collected per sample) from these data and recorded. This information is used to justify the use of permanent control measures such as ditching or draining.

Adult mosquito surveys are most commonly used because adult mosquitoes are often easier to collect and identify. These surveys determine the species present, their relative abundance, and the potential of a disease outbreak. For example, if no species of *Anopheles* mosquitoes are collected, the risk of malaria transmission is probably low.

Landing counts are the most simple and direct method used to determine which vector species in a region is feeding on humans. Biting collections are no longer used due to the increased chances of contracting vector-borne diseases using this method. Landing counts are used to determine relative abundance, host preference, place and time of activity, and species. Counts usually continue for 10-30 minutes per hour (depending on mosquito density). The data are then converted to a standard landing rate index (bites per person per hour) of each species collected for standard comparison.

Light traps are used to estimate adult populations for certain *Anopheles* species. However, many *Anopheles* species are not attracted by light, but by carbon dioxide (dry ice). Light trap collections for endophilic *Anopheles* can be enhanced for some species by placing the traps inside houses or buildings.

The detection of plasmodial sporozoites of human origin in mosquito salivary glands is important in determining vector status. The sporozoite rate is used to estimate the sporozoite inoculation rate of the human-biting mosquito population and is a key parameter in the quantitative analysis of natural transmission. Salivary gland dissection to detect plasmodial sporozoites is time consuming, requires highly technical skills, and requires fresh material. However, recently the Walter Reed Army Institute of Research and NAVIX Corporation, Camarillo, California, have jointly developed a Malaria Sporozoite Antigen Panel Assay to determine the

presence of *Plasmodium falciparum* and *Plasmodium vivax* sporozoites in mosquitoes. This test can be accomplished within 15 minutes on fresh or dried specimens. This new technology is currently being field tested at several sites worldwide. Initial results are promising as the research and development process moves towards fielding this product for army preventive medicine units.

Vector control options that are currently available for use during contingencies by the US military are: use of personal protective measures; environmental management, including; source (breeding site) reduction; larviciding, including the use of biocides; space spraying (ultra-low volume and barrier sprays); aerial spraying, and indoor residual spraying.

These various control options are aimed at reducing or eliminating vector production, reducing adult vector populations, reducing the life span of adult females and preventing vector contact with humans. The complementary or synergistic effect of two or more methods should be considered, as any one method on its own may be inadequate to successfully impact the situation.

Elimination of breeding habitats is the most environmentally safe and permanent method for reducing mosquito populations and the diseases they transmit. Breeding sites can also be made unsuitable for mosquito larvae by increasing water flow or ditching, removing protective vegetation, or other actions that completely destroy breeding sites such as filling or draining. However, permanent removal of breeding sites requires careful planning and through engineering, heavy equipment, and personnel which may not be available to a deployed military force.

Pesticides are only used by the US military as a part of an integrated pest management (IPM) program. IPM is an approach that combines a variety of control techniques (including physical, mechanical, educational, biological, and chemical) to prevent disease and injury or economic loss due to vector arthropods and pests. Since pesticides are usually a last resort, the IPM approach reduces dependency on pesticides and reduces the health and environmental risks associated with pesticide treatments.

All persons applying pesticides during military operations must be certified as Department of Defense Pesticide Applicators. This certification requires the successful completion of a three-week training course, a written test, and one year of on the job training. Every three years, certified personnel must successfully complete a one-week re-certification course and successfully pass a written exam.

Pesticide usage during military operations must be properly recorded, reported on the «Pest Management Maintenance Record» and archived, as required by the Department of Defense (23). This recording and archiving of all pesticide applications is invaluable for retrieving pesticide use records for deployments, tracking exposure of military personnel, tracking environmental exposure to pesticides, and answering inquiries. All copies of the Pest Management Report are signed by the command entomologist and forwarded to the US Army Center for Health Promotion and Preventive Medicine for permanent archiving.

Treatment of standing water with larvicides provides temporary control of mosquitoes and is more effective than adult control techniques. This method has not immediate effect on adult populations. However, this may be the most cost effective control method if troops are going to be located in an area for an extended period.

The treatment of choice to control adult mosquitoes is ultra-low-volume (ULV) spraying. ULV spraying provides adequate protection for limited periods of time. ULV insecticides must be applied on a repetitive basis (up to twice daily) to provide continuous protection in large areas with many breeding sites. ULV insecticides are applied when winds are calm (less than 10 mph) and when the ground is cooler than the air. Such temperature conditions usually occur at sunrise and sunset. However, many *Anopheles* species are active later in the evening. This is where a thorough knowledge of mosquito ecology is needed to time insecticidal sprays with periods of peak mosquito activity.

Recently, the use of backpack or hand held sprayers to apply a residual spray barrier treatment have shown promise for military situations (24). This methods involves applying a residual spray treatment of all vegetation surfaces within 30 meters of small camps or bivouac areas to establish a barrier against mosquito re-infestation.

Aerial application, either by rotary-wing or fixed-wing aircraft, requires special consideration. These operations require the authorization and supervision of a Department of Defense entomologist and qualified pest control personnel. Factors considered before use include size of treatment area, vegetation cover (canopy) and density, suitability of alternative measures, prevalence of vector borne diseases, and the prospects of increasing troop effectiveness.

In areas where vector control is carried out for some time (i.e., during extended deployments), it is necessary to determine whether current vector control activities continue to be effective. Although rigorous study designs are not possible or desirable, field expedient tests can be completed. These include insecticide resistance bioassays, adult densities, adult resting indices, human landing rate, or human blood index.

CONCLUSION

The US military has learned a great deal about malaria prevention, surveillance and control during the many deployments over the last ten years. These experiences have lead to a more proactive medical planning and medical threat assessment process. Military personnel are now equipped with a significant arsenal of personal protective measures and commanders can rely on effective unit protective measures. These combine to provide almost complete protection from nuisance and disease vectors and ultimately, from vector-borne diseases like malaria. However, all military personnel must continue to take responsibility for themselves and other unit members in preventing or minimizing the effects of malaria.

Disclaimer • The views of the author do not purport to reflect the position of the US Department of the Army or the Department of Defense.

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