# AN EVIDENCE-BASED VECTOR CONTROL STRATEGY FOR MILITARY DEPLOYMENTS : THE BRITISH ARMY EXPERIENCE

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*Med. Trop.* 2001 ; **61** : 91-98

**ABSTRACT • We describe the British Army's current strategy for controlling arthropod vectors of disease during overseas deployments. Military commanders and medical officers have different, but complementary responsibilities in achieving vector control. In this paper we define a hierarchy of evidence-based vector control guidelines. Field guidelines must be based on the best available research evidence, preferably that derived from pragmatic randomised controlled trials (RCTs), and from systematic reviews of trials. Assessing the effectiveness of different vector control measures involves a trade-off between the relative benefits and harm of different technology options. There is compelling scientific evidence that bed nets and screens treated with a pyrethroid insecticide are highly effective in protecting against nocturnally active, anthropophilic arthropods (including ectoparasites), and will reduce the incidence of malaria, leishmaniasis, lymphatic filariasis and Chagas' disease. Etofenprox and deltamethrin are the safest pyrethroids, and permethrin the least safe. Vector control strategies of probable effectiveness are the use of insecticide-treated clothing, the wearing of protective clothing, and the correct use of DEET-based topical insect repellents. Aerosol insecticides are of debatable effectiveness. Other effective vector control measures, of limited usefulness during deployments, include electric fans, mosquito coils / vaporising mats, and smoke. «Biological» vector control measures, and insect buzzers / electrocuters are ineffective. Practical insect avoidance measures, based on an understanding of vector biology, complete the military vector-control arsenal. We conclude that practical insect avoidance measures, combined with pyrethroid-treated nets and clothing, and DEET-based topical repellents, can achieve almost 100 % protection against biting arthropods.**

**KEY WORDS • Malaria - Pyrethroids - Insect repellents - British Army.**

**UNE POLITIQUE DE LUTTE ANTIVECTORIELLE ADAPTEE AUX DEPLOIEMENTS MILITAIRES SELON DES RESULTATS D'ETUDES : L'EXPERIENCE DE L'ARMEE BRITANNIQUE**

**RESUME • Nous décrivons la politique actuelle de lutte contre les anthropodes vecteurs de maladies utilisée par l'armée britannique lors des déploiements outre-mer. Le commandement militaire et les autorités sanitaires ont des responsabilités différentes mais complémentaires dans l'accomplissement de cette lutte. Dans cet article, nous présentons une liste hiérarchisée de directives de lutte antivectorielle définies selon les résultats d'études. Les directives mises en application sur le terrain doivent s'appuyer sur les meilleurs résultats de recherche, de préférence provenant d'essais pragmatiques randomisés et contrôlés, ainsi que de revues systématiques des essais effectués. L'évaluation de l'efficacité des différentes stratégies de lutte antivectorielle doit tenir compte des effets bénéfiques et néfastes, avantages et désavantages, de toutes les options disponibles. Il semble désormais clairement démontré que les moustiquaires de lit et les rideaux traités avec un pyréthroïde sont hautement efficaces contre les insectes nocturnes anthropophiles, y compris les ectoparasites, et réduisent l'incidence du paludisme, de la leishmaniose, de la filariose lymphatique et de la maladie de Chagas. L'étofenprox et la deltaméthrine sont les pyréthroïdes les plus sûrs et la perméthrine la moins sûre. Les stratégies de lutte antivectorielle dont l'efficacité semble probable sont l'utilisation de vêtements imprégnés d'insecticide, le port de vêtements protecteurs et l'utilisation correcte d'insectifuges cutanés à base de DEET. L'efficacité des insecticides en aérosol est encore débattue. D'autres stratégies de lutte antivectorielle qui semblent efficaces mais d'intérêt limité pour des forces en opération sont les ventilateurs électriques, les serpentins, la fumée. Les mesures de lutte «biologique» et les systèmes d'électrocution des insectes sont inefficaces. Des mesures pratiques d'évitement des insectes, fondées sur la connaissance de leur écologie, complètent l'arsenal militaire de lutte antivectorielle. Nous concluons que ces mesures pratiques d'évitement, associées aux moustiquaires et aux vêtements imprégnés d'insecticide, ainsi qu'aux insectifuges cutanés à base de DEET, apportent à peu près 100 % de protection contre les piqûres d'anthropodes.**

**MOTS-CLES • Paludisme - Pyréthrinoïdes - Insectifuges - Armée britannique.**

Despite the availability for most arthropod-borne diseases of effective drug and non-drug preventive measures, these diseases continue to pose a serious threat to deployed troops. A recent analysis of short missions carried out by NATO forces during the 1990s to various malaria-endemic regions found that the crude attack rate of malaria was typically

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*Table I - Vector control strategies during military deployments : the hierarchy of evidence.*

| Strategies | Responsibilities of field commanders | Responsibilities of medical officers |
|---|---|---|
| Highly effective : | | |
| • Insecticide-treated bed nets and screens | To ensure that every transitee is issued with a bed net prior to deployment, and not after arrival in theatre.<br>To ensure that, prior to deployment, all bed nets are correctly treated with an approved pyrethroid insecticide.<br>To encourage the use of pyrethroid-treated screens over the doors and windows of tents and dormitory blocks. | To advise commanders on the correct use of treated bed nets and screens, and on the recommended re-treatment interval for these items (normally 6 weeks to 6 months). |
| Probably effective : | | |
| • Insecticide-treated clothing | To ensure that every transitee is issued with one full set of uniform, correctly treated with an approved pyrethroid insecticide, prior to deployment.<br>To ensure that the entire clothing system (i.e., hat, vest, shirt, jacket, trousers, socks) is pre-treated with a pyrethroid insecticide. | To advise commanders on the correct use of treated clothing, and on the recommended re-treatment interval for clothing (normally 6 weeks). |
| • Protective clothing | To ensure that all troops wear long-sleeved shirts and trousers, especially if outdoors in the evening or at night. | To advise commanders. |
| • Topical insect repellents | To ensure that all troops apply a DEET-based repellent to exposed skin, especially if outdoors in the evening or at night. | To advise on the possible adverse effects of DEET, especially if left applied to flexures overnight. |
| Debatably effective : | | |
| • Aerosol insecticides | To ensure that aerosol insecticides are used only by trained environmental health personnel, in line with standard instructions. | To advise commanders. |
| Ineffective : | | |
| • Biological vector control buzzers/electrocuters | To ensure that personnel under their command do not use ineffective vector control measures, and that these ineffective items are not procured with unit funds, through local purchase. | To advise commanders. |

1-2 p. 100, and in one case was 27 p. 100 (1, 2). The reasons for this continuing failure to control vector-borne disease during military operations are :

• *Organisational* : imperfect threat appreciation by military planners and logisticians, inadequate risk communication, and failure of field commanders to recognise and discharge their vector control responsibilities.

• *Medical* : failure of medical officers to prescribe the correct prophylactic drugs or vaccinations, to give appropriate advice on the common adverse effects of these agents, and to advise commanders correctly.

• *Personal* : failure by individual soldiers (whether through ignorance, forgetfulness or intentional non-compliance) to adhere to chemoprophylaxis, or to non-drug protective measures against arthropod vectors of disease.

Military vector control policies must be based on the best available research evidence, preferably that derived from pragmatic randomised controlled trials (RCTs), and from systematic reviews of trials (3). The evidence base for existing vector control policies must be continuously reviewed by a central military scientific cell, and any changes to that policy made only after a rigorous appraisal of the benefits and harms of the proposed change. As an example of a necessary change to military policy, the use of dichlorodiphenyltrichloroethane (DDT), although cheap and highly efficacious, is no longer a military option for environmental vector control owing to widespread public concern about its long-term persistence in food chains (4). Finally, any changes in central policy need to be promulgated swiftly and consistently to the lowest level of use, and incorporated immediately into training programmes and instruction manuals.

In Table I we show the non-drug hierarchy of scientific evidence which currently, as at November 2000, underpins the various vector control strategies in place in the British Army. The table also distinguishes the respective domains of field commanders, and of medical officers. In the text which follows we elaborate in turn on each of the tiers of evidence shown in the hierarchy.

## HIGHLY EFFECTIVE CONTROL MEASURES

### Insecticide-treated bed nets and screens.

A systematic review of bed nets treated with pyrethroid insecticides found that they effectively reduce malaria morbidity and mortality in many different epidemiological settings (5). Insecticide-treated nets (ITNs) also provide significant protection against sandfly vectors of leishmaniasis (6, 7), and some protection against lymphatic filariasis (8) and Chagas' disease (9).

Pyrethroids are effective against mosquitoes, flies, ticks and chiggers, and at present are the only group of insecticides cleared for use on ITNs (10). This is due to the rapid «knock-down» effects and high insecticidal potency of pyrethroids at low dosages, combined with their relative safety for human contact and domestic handling (11) ; this relative safety is discussed further below.

In some cases, the efficacy of pyrethroids is augmented by their apparent repellency towards mosquitoes, and

*Tableau II - Using a bed net correctly : a soldier's guide (Assuming a bed net impregnated with pyrethroid insecticide).*

| | |
|---|---|
| 1 | Make sure that you are issued with a bed net impregnated with pyrethroid prior to arriving in a malaria-endemic area. |
| 2 | Make sure you sleep under this bed net at all times, whether indoors or out of doors. |
| 3 | Check your bed net regularly for any holes, and repair these immediately. |
| 4 | Before retiring at night, tuck the bed net carefully under your camp bed, mattress or sleeping mat. |
| 5 | During the night, try and ensure that no part of your body touches the net, as insects will bite you through the mesh. |
| 6 | Make sure that your bed net is re-treated regularly with pyrethroid. |
| 7 | If for any reason you do not have a pyrethroid-treated bed net, try and sleep surrounded by colleagues who do have treated bed nets. |

it has been shown experimentally that when one ITN is used in a house, it helps to reduce the number of mosquito bites experienced by others sleeping without a net in the same house (12). An RCT found that when ITNs are used by the majority of the community, people who sleep without treated nets may also receive fewer bites of infective *Anopheles* mosquitoes (13). This recent research finding may be usefully applied in a military scenario, where, for example, not every member of a patrol has a treated bed net : commanders should ensure that in such circumstances, individuals without ITNs sleep surrounded by those with treated nets.

Another beneficial property of ITNs is that they reduce populations of human ectoparasites, such as bedbugs and lice (14).

Because diseases such as malaria can be transmitted by even a single infective bite, field commanders should appreciate that bed nets need to be treated with a pyrethroid *prior to deployment,* and not after arrival in a malaria-endemic area. Any holes in the nets must be repaired before further use. Before retiring at night, the treated bed net should be tucked in carefully under the camp bed, mattress or sleeping mat (15). The sleeper should try and ensure that no part of his or her body touches the net during the night. Wherever possible, pyrethroid-treated mesh or netting should also be fitted as screens around the doors, windows and other openings of tents and dormitory blocks (16). Under normal conditions of use, pyrethroids remain active for up to six months, even through several launderings (17, 18).

Table II is a guide for soldiers on the correct use of pyrethroid-impregnated bed nets.

## Safety of pyrethroids.

The WHO Pesticide Evaluation Scheme (WHOPES) has approved, or is soon to approve, six different pyrethroids for the treatment of nets (19). These pyrethroids are alpha-cypermethrin, cyfluthrin, deltamethrin, etofenprox, lambda-cyhalothrin and permethrin.

Pyrethroids entering the systemic circulation are rapidly metabolised through ester hydrolysis to much less toxic metabolites (20). At the treatment concentrations recommended, therefore, these approved pyrethroids pose little or no hazard to people treating the nets, or to the users of treated nets (19). There is nevertheless a potential risk from the accidental ingestion of pyrethroid (as may occur, for example, in a household containing children), and an approximate safety scale has been constructed for the six approved pyrethroids, based on the $LD_{50}$ in a 10-kg child (11). On this scale, etofenprox and deltamethrin are the safest pyrethroids (safety factor 200 and 12.5 respectively), and permethrin is much the lowest (safety factor 0.7) (11).

The British Army's current policy is to impregnate bed nets with a commercial permethrin solution known as Peripel 10. Mass impregnation is carried out by personnel wearing butyl rubber protective gloves, and the process is supervised by trained regimental or environmental health staff. The dilution rate for nylon netting is one part of Peripel® 10 to 29 parts of cold water (if protection is intended to last for six weeks), or one part of Peripel® 10 to eleven parts of water (if protection is to last for six months). Permethrin has a strong smell in the liquid state, but this disappears when dry ; once dry, nets may be safely handled with bare hands. However, because of the safety issues outlined above, an alternative pyrethroid to permethrin is currently being considered.

## PROBABLY EFFECTIVE CONTROL MEASURES

There are three vector control measures which, although not yet assessed rigorously through systematic reviews, have nevertheless been shown to be effective through small, clinically-focused RCTs, or through very extensive empirical evidence, or through larger RCTs with non-clinical or proxy outcomes (for example, mosquito counts, or insect bite rates). These three measures are insecticide-treated clothing, protective clothing and topical insect repellents. Generically, these may be termed « probably effective » vector control measures (15).

## Insecticide-treated clothing.

The effectiveness of treating military clothing with insecticide was demonstrated experimentally in an RCT involving eight paired U.S. Air Force personnel in Alaska (21). Participants wearing permethrin-treated uniforms together with a polymer-based 35 % DEET (N,N-dyethyl-3-methylbenzamide) topical repellent had more than 99.9 % protection against culicene mosquitoes (1 bite per hour) over 8 hours, while unprotected controls received an average of 1 188 bites per hour ($p < 0.01$). In other, empirical studies, permethrin treatment of fabric was shown to be effective against a wide range of other arthropods, including ticks, fleas, bed bugs, horse flies and body lice (17, 22).

Military clothing can be treated with insecticide through one of several methods, namely :

• *Pyrethroid impregnation*

Clothing which is 100 % cotton, or else a 50/50 cotton-polyester mix, can be impregnated with pyrethroid on the same principles as bed net impregnation, although the pyrethroid dilution rates differ (23). It is important that the entire clothing system is impregnated (i.e. hat, vest, shirt, jacket, trousers and socks). As with bed nets, clothing impregnation should be carried out prior to deployment to a malaria-endemic area, and not after arrival in theatre. The protective effect of impregnation will normally last at least six weeks, although machine washings with warm water and detergent will progressively degrade the effect (24).

• *Pyrethroid spraying*

Although the protective effect is less powerful and less persistent than with impregnation, clothes may simply be hung up outdoors and sprayed with an aqueous solution of permethrin for 30-45 seconds on each side, aiming to just moisten the fabric (25, 26). The clothes are then left in place to dry 2-4 hours before wearing. The permethrin remains active for at least 2 weeks, even through several launderings. In military scenarios of extreme urgency, clothing can even be sprayed while it is still being worn (23).

• *DEET impregnation*

As an alternative to using pyrethroids, cotton garments can be impregnated with 30 ml of DEET in 250 ml of water (27). If DEET-treated garments are worn only briefly, and stored in a plastic bag between wearings, the repellent effect can last for many weeks (28). Alcohol-based DEET formulations can also be applied directly to sleeping bags, tents, mesh window screens, etc (10). DEET is discussed further below.

For pragmatic reasons, the clothing treatment method currently favoured by the British Army is mass impregnation of clothing with pyrethroid insecticide just prior to an overseas deployment, using Peripel® 10 (i.e., permethrin) diluted with 49 parts of cold water. The British Army's lightweight clothing system is not at present impregnated with pyrethroid at the point of manufacture, although there are plans to introduce this sensible innovation in the near future. NBC clothing and individual protective equipment are not treated with pyrethroid at present.

## Protective clothing.

There is one observational study, and much empirical evidence, to suggest that simply wearing long-sleeved shirts and trousers protects against arthropod-borne disease. A questionnaire survey of 89,617 European tourists returning from East Africa found that wearing long-sleeved shirts and trousers significantly reduced the incidence of malaria ($P = 0.02$) (29). The wearing of long-sleeved clothing is particularly important at dusk, which is when anopheline mosquitoes start to feed (15).

In areas of intense activity by biting arthropods, some military forces issue face veils to patrolling; these veils have been tried in the British Army, but have not proved popular. British troops in the Far East during the Second World War experimented with net gloves, but these also were not liked (Lieutenant Colonel William Thom, personal communication).

Insects prefer landing on dark rather than light surfaces (27). Where tactical considerations do not rule this out, deployed troops should be encouraged to wear light rather than dark colours.

Military footwear should be of the closed variety, and open-toed sandals and shoes should not be permitted. Cloth or canvas shoes, if used, should be treated with pyrethroid insecticide. The space between trousers and footwear should be closed, to discourage adherent tics (30).

## Topical insect repellents - DEET.

There is some experimental evidence, and much empirical evidence, that topical insect repellents are effective in reducing bites from arthropod vectors of disease (15).

N,N-dyethyl-3-methylbenzamide (DEET) is a broad-spectrum repellent, formerly known as N,N-diethyl-m-toluamide. It was developed by the U.S. Department of Agriculture, and was patented by the U.S. Army in 1946 (10). DEET is highly effective in repelling mosquitoes, particularly those of the genera *Culex* and *Aedes,* although it is relatively less effective against the genus *Anopheles* (23). DEET is therefore especially effective against dengue fever, which is transmitted by day-biting *Aedes aegypti* (30). DEET is also effective against biting flies, chiggers, fleas and ticks (10).

DEET is manufactured in either an alcohol base, or as an extended-release form in a polymer base, the latter having the advantage of greater persistence for reduced DEET concentration (31-33). DEET is available in concentrations ranging from 5 % to 100 %, although under normal climatic conditions DEET-containing products with concentrations of greater than 50 % do not confer greater protection, but can merely be applied more sparingly (34). DEET products are available commercially as solutions, lotions, creams, gels, aerosol sprays, soaps and towelettes (10).

There are no military RCTs of DEET use, and no RCT on the efficacy of DEET which had clinical illness as an outcome (15). However one small RCT involving eight civilian participants in a Colombian forest setting compared repellent soap (20 % DEET and 0.5 % permethrin) versus placebo soap and found repellent soap to reduce the number of sandfly bites at 4 and 8 hours ($p < 0.05$) (35). Although efficacious, the use of DEET-containing soap is considered to be not very user-friendly, in that the soap has to be applied to the skin, but must not be rinsed off (23).

As with all topical repellents, DEET should be applied lightly to all areas of exposed skin, including the face, scalp, wrists, hands and ankles. Unprotected skin even a few centimetres away from a treated area can be attacked by hungry mosquitoes (36). The aim is to just lightly cover the skin, and not to saturate it. DEET should not be applied under clothing, since abrasion will reduce its repellency (10). Because of DEET's irritant properties, contact with eyes, mouth and genitals should be avoided, and the palmar aspects of the hands should be wiped thoroughly (or washed carefully) after applying the repellent. For the same reason, DEET should not be applied over cuts, wounds, inflamed, irritated or eczematous skin (10).

*Tableau III - Correct use of topical insect repellent : a soldier's guide. (Based on Reference 10, and assuming a polymer-based, DEET cream formulation.)*

| | |
|---|---|
| 1 | DO use repellent on all areas of exposed skin, including the face, scalp, wrists, hands, ankles. |
| 2 | DO use just enough repellent to lightly cover the skin, not to saturate it. |
| 3 | DO avoid contact with eyes, mouth and genitals. |
| 4 | DO wipe palms and fingers thoroughly after applying repellent, to prevent accidental transfer of repellent to eyes, mouth or genitals. |
| 5 | DO wash repellent off with soap and water, once indoors. |
| 6 | DO NOT apply repellent to areas of skin covered by clothing. |
| 7 | DO NOT apply repellent over cuts, wounds, inflamed, irritated or eczematous skin. |
| 8 | DO NOT inhale repellent vapour. |
| 9 | DO NOT allow repellent to come into contact with plastic (e.g., spectacle frames, computer keys) or leather (e.g., watch straps). |
| 10 | DO NOT keep re-applying repellent : once every 8 hours is sufficient (except in very humid conditions, when repellent should be applied more frequently). |

Note : Pregnant personnel should not use a DEET-based repellent. They should seek advice from a medical officer.

DEET attacks certain plastics, such as spectacle frames and the plastics of some weapons parts, computers and other military equipment. Soldiers should be warned of this problem, and advised that this is another important reason for wiping the hands thoroughly after using DEET (15). DEET will also damage leather, rayon, other synthetic fabrics, and painted and varnished surfaces. It will not however damage natural fibres such as cotton or wool, and it has no effect on nylon (10). The use of DEET in combination with a sunscreen will diminish the effectiveness of the latter : in a controlled study involving 15 participants, there was a mean decrease in sun protection factor of 33.5 % when DEET and the sunscreen were applied sequentially (37). It has also been reported that there is incompatibility between DEET-containing repellent and the camouflage cream used by active duty U.S. soldiers (23).

Table III is a guide for soldiers on the correct use of DEET as a repellent.

The British Army's standard insect repellent since 1995 has been a slow-release, polymer-based cream formulation containing 32 % DEET. This has the trade name Ultrathon®, and is procured from the Amway Corporation, New York. It is packaged in a matt green polythene tube, and is standard issue to all troops at short notice to deploy overseas. Ultrathon® is effective for 8 hours in normal climates, but needs to be re-applied more frequently in very hot or humid conditions. There is anecdotal evidence that off-duty personnel do not like the odour and greasy feel of this product, but it appears to be adequately tolerated by British troops on active duty in areas with high insect biting rates.

## Safety of DEET.

DEET has been in continuous use for over 40 years, resulting in billions of applications worldwide (38). There are thus good data for assessing its apparent safety. There is a small risk of encephalopathic toxicity in young children after excessive use of DEET, and there have been two reported fatalities ; however, there are few reports of harms in adults (15, 23). There is a published case series of bullous eruptions observed in the antecubital fossae of soldiers who applied DEET to this area of the body before retiring at night (39). The air-tight occlusion of the antecubital fossa during sleep may explain this adverse effect, and soldiers should be advised to wash DEET repellent off with soap and water, once indoors (38). There is a published case series of systemic toxic reactions (confusion, irritability, insomnia) in U.S. National Park employees after repeated and prolonged use of DEET (40).

Because of a theoretical potential for mutagenicity, pregnant women (including female soldiers who may become pregnant while on active duty) should not use DEET (15, 23).

## Other topical insect repellents.

A number of other, commercially-available insect repellents have potential for use during military deployments. These repellents include ethylhexanediol, which has greater repellency than DEET against Anopheles mosquitoes, but which has an estimated duration of action of only 1-2 hours (41).

Several plant-based repellents exist, such as citronella, and eucalyptus oil ; however, the benefits and harms of these products have not been assessed scientifically (15, 38).

## DEBATABLY EFFECTIVE CONTROL MEASURES

Environmental health teams are an important and necessary element of any deployed military formation. Such teams normally have a responsibility for large-scale environmental vector control, through the mass aerosol delivery of insecticide. This may be achieved through man-portable devices, such as the Swingfog, or through a vehicle-mounted, thermal aerosol generator. The expense of the latter system makes it impractical, other than in an urban setting, and only where there is an established or developing vector-borne epidemic.

Aerosol insecticides are of two classes, namely :

• *Knockdown insecticides* : these insecticides are normally delivered as a fog or mist in defined spaces, and have an immediate knockdown effect on flying insects. Their usefulness however has not been assessed against any clinical criteria, and so they are at best debatably effective (15).

• *Residual or persistent insecticides* : these insecticides are applied to the surfaces of a tent or building, where they remain toxic to crawling insects for some days, or weeks (42). There are no military RCTs of their use. An RCT of indoor residual spraying in Pakistan with alphacypermethrin, a WHO- approved pyrethroid, found a reduction of *Plasmodium falciparum* malaria in sprayed communities, compared to unsprayed controls (P = 0.03) (43).

Because of the potential environmental impact of large-scale insecticide aerosolisation, together with some uncertainty regarding its efficacy in a military setting, field commanders should ensure that aerosol insecticides are used only by trained environmental health personnel, in line with standard instructions.

## OTHER EFFECTIVE CONTROL MEASURES

A number of other vector control measures have been shown to be effective in the indigenous setting, and/or in tourists and business travellers (15). These control measures, which are unlikely to be of practical use during most military deployments, are listed here for completeness, and are as follows.

• *Electric fans* : an observational study of various antimosquito interventions in six experimental huts in Pakistan villages found that fans significantly reduced catches of culicene mosquitoes ($P < 0.05$), but did not significantly reduce catches of blood-fed anopheline mosquitoes (44).

• *Mosquito coils and vaporising mats :* an RCT in 18 houses in Malaysia of various mosquito coil formulations found that coils reduced populations of culicene mosquitoes by 75 % (45). An observational study of pyrethroid vaporising mats in six experimental huts in Pakistan villages found that the mats reduced total catches of blood-fed anopheline mosquitoes by 56 % (44).

• *Smoke* : a controlled trial in which five small fires were tended on five successive evenings in a village in Papua New Guinea found a smoke-specific and species-specific effect from different types of smoke. Catches of one anopheline species were reduced by 84 % through burning betelnut (95 % C.I. 62 % to 94 %), by 69 % through burning ginger (95 % C.I. 25 % to 87 %), and by 66 % through burning coconut husks (95 % C.I. 17 % to 86 %) (46).

## INEFFECTIVE CONTROL MEASURES

Ineffective vector control measures may be classed as :

• *Ineffective biological control measures* : these ineffective measures include the growing of plants with supposed insect repellent properties, and the encouragement of natural predation by erecting bird or bat houses close to living quarters (47, 48). These measures appear to be ineffective (15).

• *Insect buzzers and electrocuters* : there is a flourishing commercial market in ultrasonic buzzers, which purportedly repel insects through high-pitched acoustic emissions, and in insect electrocuters, which lure and electrocute flying arthropods (49, 50). Again, these measures appear to be ineffective (15).

Field commanders should ensure that deployed personnel under their command do not use ineffective vector control measures, even when these are recommended by the indigenous population. Commanders should ensure that these ineffective items are not procured with unit funds, through local purchase arrangements.

## PRACTICAL BITE AVOIDANCE - ROLE OF COMMANDER

### Camp siting and camp discipline.

To the scientific control measures outlined in this paper must be added environmental manipulation, to avoid proximity to biting arthropods, and to prevent possible disease vectors from multiplying. Wherever possible, camps should be sited on high and open ground, away from standing water. If possible, a windy site should be chosen, since mosquitoes (which may transmit malaria, dengue fever, Japanese encephalitis, yellow fever and many other haemorrhagic diseases) are particularly reluctant to fly in windy conditions (51). Because many insect vectors do not fly far from their breeding sites, grass and scrub within a 400-metre radius of the living quarters should be cut low.

Within the same 400-metre radius, a weekly patrol should be mounted to eliminate sources of standing water where anopheline mosquitoes might breed, such as : tree stumps, discarded tyres, cans and bottles (15). Any fire buckets and the like which intentionally contain water should be emptied once weekly, and the water replaced. These measures will effectively disrupt the larval stage of the mosquito's life cycle; this stage lasts approximately one week (10).

In malaria-endemic areas, outdoor activities by troops should be severely curtailed as soon as dusk sets in, and they should remain indoors until daybreak. They should not go outside for ablutions.

### Camp infection control committee.

The commander should establish and chair a camp insect control committee, to co-ordinate and enforce all the above activities. Membership should include the quartermaster, the medical officer and an environmental health representative. The committee should keep proper written records, and inspecting senior officers should be responsible for auditing these written records.

Table IV is a guide for field commanders on practical bite avoidance measures.

*Tableau IV - Practical measures to avoid biting insects : a guide for field commanders. (Assuming a military camp sited in a malaria-endemic area).*

| | |
|---|---|
| 1 | Try and site your camp on high, open and if possible windy terrain, away from standing water. |
| 2 | Ensure that grass and scrub within a 400 metre radius of the camp are cut short regularly, so as not to harbour insects. |
| 3 | Ensure that a patrol goes out once a week, on the same day of each week, to eliminate sources of standing water within the 400-metre radius (e.g., tree stumps, discarded tyres, cans and bottles). Water in fire buckets and the like should be changed once weekly by this patrol. |
| 4 | Ensure that your troops discontinue all their non-essential outdoor activities as soon as dusk sets in. All ablutions after dark should take place indoors. All troops not on guard duty, or undertaking essential night patrols, should remain indoors until daybreak. |
| 5 | Establish a camp infection control committee, chaired by yourself, to co-ordinate and enforce all the above. |

## CONCLUSION

Effective control of arthropod vectors of disease involves a co-ordinated, systems approach to a complex environmental challenge (26, 52). The field commander must work closely with his medical staff, and the advice of the medical officer must reinforce the actions of the commander. Education of the individual soldier is paramount, since effective vector control measures are often non-intuitive, and they will be implemented badly or not at all if there is thought to be no threat (53). The importance of correct vector control must be constantly reinforced through realistic training, and through administrative instructions and training aids which are accurate, up-to-date and consistent.

In summary, the use of pragmatic measures of insect avoidance, together with a combination of pyrethroid-treated nets and clothing for all troops, and the correct use by all of a DEET-based topical repellent, can achieve almost 100 % protection against biting arthropods in any military setting (10, 54).

***Acknowledgements*** *- The authors thank Lieutenant Colonel W. Thom (ex-Indian Army Medical Corps), Major S. Kitchener (Australian Army Malaria Institute), P. Garner (Liverpool School of Tropical Medicine), and J. Maunder (Medical Entomology Centre, Cambridge), for their advice during the manuscript preparation.*

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