SMOKE AS A FORM OF PERSONAL PROTECTION AGAINST MOSQUITOS, A FIELD STUDY IN PAPUA NEW GUINEA

Raoul Vernède[1], Marnix MM van Meer[1], and Michael P Alpers[2]

[1]Wageningen Agricultural University, Department of Entomology, The Netherlands; [2]Papua New Guinea Institute of Medical Research, Goroka, Papua New Guinea

Abstract. Smoke from burning different kinds of vegetation or wood is often used as a cheap personal protection measure against mosquitos during the evening. To test the efficacy of smoke, a comparative field trial was conducted in the Wosera District, Papua New Guinea. Repellency of smoke from burning wild mango wood (*Mangifera* spp), leaves from betelnut (*Areca catechu*), wild ginger (*Alpinia* spp) and coconut husks (*Cocos nutifera*) was assessed using man-biting catches. A mosquito species and smoke specific repellency was found. *An. karwari* was repelled by coconut husks (66% CI 17-86%), ginger (69% CI 25-87%) and betelnut (84% CI 62-94%) leaves. Culicines were repelled by mango wood (57% CI 6-80%), coconut husks (62% CI 18-83%), ginger (75% CI 45-88%) and betelnut (64% CI 22-84%) leaves. For *An. koliensis* no repellency due to smoke was found. In combination with untreated or impregnated bed-nets, smoke may contribute to a reduction of mosquito transmitted diseases.

INTRODUCTION

In Papua New Guinea malaria is mainly transmitted by three members of the *Anopheles punctulatus* Dönitz group of mosquitos: *An. punctulatus*, *An. koliensis* Owen and *An. farauti* Laveran No. 1 (Charlwood *et al*, 1986). Bednets are used to protect sleepers against biting insects during the night. Sometimes these nets are impregnated with an insecticide. In the Wosera District, for example, the frequency of non-impregnated bednet utilization varied widely from villages where almost no-one uses a bednet to villages where many people use a bednet (USAID Progress Report, unpublished, survey of July 1990). However in hyperendemic to holoendemic malaria areas, the use of bednets alone is not sufficient to achieve a reduction of the vectorial capacity and malaria prevalence (Rozendaal and Curtis, 1989). Although the number of early evening biting anophelines is often relatively low in comparison with mosquitos biting late in the night, they might be the greatest source of malaria infection for bednet users. Relatively large numbers of culicines in the early evening can account for the transmission of other mosquito-borne diseases, such as dengue, bancroftian filariasis, Ross River fever and Murray Valley encephalitis.

Correspondence : Dr R Vernède, Wageningen Agricultural University, Department of Entomology, Binnenhaven 7, 6709 PD Wageningen, The Netherlands.

During the early evening villagers could apply skin repellents, wear protective clothing or burn mosquito coils or wood and leaves, to deter mosquitos. Due to the high costs of some of these items or the hot tropical climate, the first two methods are not popular. In the Wosera District the frequency of people using smoke, inside or outside houses varied widely from about 40% to 90% in eight villages (USAID Progress Report, unpublished, survey of May 1990).

Little work has been done on the efficacy of smoke as personal protection against mosquito bites. Lindsay and Janneh (1989) reported that in The Gambia "Churai"-smoke is as effective in reducing the man-landing-rate of culicines as is the use of a repellent soap (20% DEET + 0.5% Permethrin). "Churai" is a collective name for a variety of perfumed resins and wood kernels, obtained predominantly from the tree *Daniellia oliveri*.

In February 1991 a survey was conducted in four villages in the Wosera District to investigate the relationship between bednet use and the prevalence of a history of malarial attacks. The survey included questions on traditional methods used against biting insects in the evening. The results showed that people use different kinds of plant material such as wood, coconut husks, leaves of betelnut and wild ginger to produce smoke. We report here the relative effects of different traditional smoke-types on the composition of captured mosquito populations during the early part of the night and discuss their effects on host-seeking behavior and implications for vector control.

MATERIALS AND METHODS

During the rainy season in 1991, a field trial was conducted in the Wosera District (East-Sepik Province) at Nale-1. The Wosera is an area 13 to 18 km south west of Maprik and is located in the rolling forest and grass covered foothills of the Prince Alexander mountains. Nale-1 is 4 km east of the Institute of Medical Research field station in Kunjinginі-1. Repellency, defined as a behavioral modification of the host-seeking process of mosquito due to interference of specific volatile chemicals, was assessed using man-biting catches for five consecutive nights from 1800 to 2400 hours. Catches were made under each house or under the eaves of five similar constructed houses on stilts about 10 m apart. Ten local male collectors sat in pairs at 1-2 m distance from the source of the small smoldering fire, facing each other. Each collector sat on the ground or on a little wooden stool with his arms, legs and feet exposed and collected mosquitos using a torch and an aspirator.

In this trial five treatments were compared; no smoke, smoke produced by burning of wild mango wood (*Mangifera* spp), coconut husks (*Cocos nutifera*), leaves from betelnut (*Areca catechu*) and wild ginger (*Alpinia* spp).

The trial was performed using a 5 × 5 Latin-square design to compensate for the variation in number of mosquitos caught between treatments, pairs of catchers, seating position and on different nights. Collected mosquitos were killed, counted, separated into genera and anophelines were identified according to their species. Statistical analysis were done by Least Significant Difference (LSD) test and Dunnett's two sided test for comparing all means with the control.

To standardize the emission of smoke about 5 to 8 kg (mean 7.0 kg, SD from 1.2 to 3.7 kg) of wood and leaves were burnt per treatment during each night. The weights were constant for the four plant materials ($df = 3$ and 12, $F = 1.04$, $p = 0.41$) and among the five nights ($df = 4$ and 12, $F = 0.91$, $p = 0.49$, two-way ANOVA). It was explained to the collectors that during the evening the smoke production should be constant.

RESULTS

During the five nights of collection from 1800 to 2400 hours a total of 958 anophelines and 606 culicines was collected. 57% of the mosquitos were *An. koliensis* and 35% *An. karwari*. Only low numbers were collected of *An. farauti* (4%), *An. punctulatus* (3%), *An. bancrofti* and *An. longirostris* (1%).

The majority of *An. koliensis* (72%) were caught from 2100 to 2400 hours and *An. karwari* (73%) from 2200 to 2400 hours. Culicines (69%) were collected mainly during the first two hours of collection (1800 to 2000 hours). The influence of the different smoke-treatments on the total number of captured *Anopheles* and culicines per treatment per night is shown in Table 1. No means and standard deviations are given since figures are biased by site and by day influences.

Table 1

The number of *Anopheles* mosquitos and culicines (in parentheses) captured by pairs of collectors exposed to different types of smoke over five consecutive nights at Nale-1, Papua New Guinea, April 1991.

Night	Smoke-treatment					Total
	No. smoke	Mango wood	Coconut husks	Ginger leaves	Betelnut leaves	
1	72 (109)	72 (27)	73 (16)	35 (16)	17 (11)	269 (179)
2	47 (53)	28 (11)	16 (31)	22 (16)	39 (19)	152 (130)
3	38 (37)	61 (9)	25 (6)	37 (20)	7 (10)	168 (82)
4	36 (7)	47 (14)	21 (9)	25 (1)	39 (13)	168 (44)
5	102 (64)	48 (39)	15 (27)	21 (20)	15 (21)	201 (171)
Total	295 (270)	256 (100)	150 (89)	140 (73)	117 (74)	958 (606)

Table 2

The percentages reduction in landing catches with 95% confidence interval of *An. karwari*, *An. koliensis* and culicines mosquitos captured by pairs of collectors exposed to different types of woodsmoke over five consecutive nights at Nale-1, Papua New Guinea, April 1991.

Treatment	*An. karwari*	*An. koliensis*	culicines
Mango wood	35% (-58-73%)	-21% (-123-35%)	57%* (6-80%)
Coconut husks	66%* (17-86%)	38% (-15-67%)	62%* (18-83%)
Ginger leaves	69%* (25-87%)	27% (-36-60%)	75%* (45-88%)
Betelnut leaves	84%* (62-94%)	38% (-15-67%)	64% (22-84%)

* Least significant difference test with $p < 0.05$.

Percent repellency is defined as the difference between the number of mosquitos captured by control and treated subjects expressed as percentages. Table 2 presents the percent repellency in relation to the control and the 95% Confidence Intervals (CI), using the LSD-test. For *An. karwari* significant different landing rates were found between no smoke and smoke from burning coconut husks and leaves from wild ginger and betelnut. Landing rates of *An. koliensis* did not show a significant reduction caused by the smoke. However the numbers of culicines collected were significantly different between no smoke and the other four smoke treatments. Using the more conservative Dunnett's test, however, revealed only significantly different catches for *An. karwari* between no smoke and smoke from burning leaves from wild ginger and betelnut. For culicines there were only significant differences between no smoke and smoke from wild ginger leaves.

The meteorological conditions were relatively constant over the five nights with the excepion of the third and fourth night when some rain fell in the early evening. The wind speed was very low to absent but the cloud cover varied widely during the five nights. The first night the moon rose at 2100 hours and each consecutive night an hour later.

DISCUSSION

Smoke produced by burning plant materials in this study appeared to be a simple and effective method for repelling man-biting mosquitos. A species and smoke specific repellency was found.

For *An. kawari* a mean reduction of man landing rates of 66% for coconut husks, 69% and 84% for betelnut respectively gingerleaves was recorded. Culicines were repelled by all four different types of wood and plant smoke (57% up to 75%). However no repellency due to smoke was found for *An. koliensis*. Although these experiments were conducted in outdoor situations they corrobate the results of Grooting (cited by Takken *et al*, 1990) in Indonesia, which demonstrated that unimproved, smoke-stained houses were 3-to-4-times less attractive for mosquitos to enter than improved houses. Grooting's hypothesis was that the unimproved houses - because of the smoke - were unattractive for mosquitos and difficult for them to enter, while after house improvement there was no more smoke to keep them away and the houses became easily accessible through the ventilation openings.

In which way smoke or in general a volatile chemical can achieve a reduction of the man-landing rate? It is probably caused by one or a combination of the following principles. First it could act as a repellent and deter mosquitos due to smell. Secondly it could be a chemical (*eg* DEET) or mechanical (*eg* smoke particles) irritant and act, for example, on the antennae or other part of the mosquito. Both would load to a kind of exodus of the mosquitos. Thirdly, smoke could work as a disguisant and overlap or camouflage the cues emitted by the host.

Species-dependent sensitivity to different chemical host-cues or differences in searching behavior could be an explanation for the diverse response of the mosquitos to smoke. Since each type of smoke elicits a differential response in host-seeking behavior, it is not possible to extrapolate the results for one species to other mosquito species.

What is the relation between the human blood index (HBI) of different mosquito species and smoke repellency? The HBI is an estimation of the blood-sucking preference and gives an indication of the mosquito feeding preference for humans hosts. In Madang Province the HBI varied widely among nine villages with a mean of 0.63 for *An. koliensis*, 0.55 for *An. punctulatus* and 0.12 for *An. farauti* (Burkot *et al*, 1989). No direct information is available for *An. karwari*, although Wepster (1953) reported than *An. karwari* preferred buffalo to human blood ($1^1/_2$: 1). But due to a scarcity of cattle *An. karwari* is considered to play a role in malaria transmission in Papua New Guinea. If *An. koliensis* is more anthropophilic than either *An. karwari* and culicines, it may well be that it is more successful in discriminating odorous molecules and seeking human hosts in the presence of smoke.

Another comparable method of repelling mosquitos, already widely used in Asia, is the mosquito-coil, which is usually made of dried pyrethrum flowers or pyrethrum extract, with jute or a similar filling agent to keep the rate of smoldering steady. Although the repellency of mosquito coils is not totally clear from a study in Zaire (Coene *et al*, 1989), their effectiveness, which is comparable to smoke, is well attested by studies in Tanzania, Papua New Guinea, The Gambia and Malaysia (Hudson and Esozed, 1971; Smith *et al*, 1972; Charlwood and Jolley, 1984; Lindsay and Janneh, 1989; Yap *et al*, 1990). These studies have reported measures of protection which ranged from approximately 40% to 80% reduction in landing rates. Despite such promising results, mosquito coils have yet to prove their acceptability as an appropriate vector control technology in Papua New Guinea.

While it is desirable to try out standardized laboratory tests of traditional methods under more controlled conditions, they may miss out important features of the field situation. In the field there may be wide variations over both time and space in the biting densities of natural insect populations, seasonal changes in the composition of the plant-material, and unpredictable weather. However, these difficulties should not be insurmountable; in this study a Latin square design was used, measuring landing rates with different smoke types over five collecting stations in five consecutive nights. It is not necessary to understand all the complex and interacting variables controlling the attraction of landing mosquitos to hosts; an effective repellent should reduce biting for everyone in a range of conditions. In this trial, there were far too many factors other than the smoke which are expected to influence the amount of biting at any five stations in the study area. Proximity to other people, vegetation, breeding sites, orientation to wind and individual differences between collectors (*eg* motivation, personal attraction, experience) may all be expected to affect the numbers collected. But over many occasions their influence should even out when the five smoke treatments are compared.

The results of this study suggest that smoke produced by burning these local plant species has a repellent effect on the number of mosquitos attacking man. It is yet to be proven if it has any appreciable impact on the incidence of malaria in Papua New Guinea. In a holoendemic area in The Gambia Snow *et al* (1987) found no significant reduction of the malaria incidence, as measured by splenomegaly, point prevalence parasitemia and packed cell volumes, in children as a result of the use of "Churai" - smoke in a room at night. Presumably no repellent effect of "Churai" was measured because all the children were sleeping under impregnated bednets. However smoke as personal protection during the evening in combination with non or impregnated bednets during the night, may reduce the malaria incidence.

Despite its irritant and toxic effect on eyes and the respiratory system, smoke produced by certain plant species which contain botanical insecticides or repellents may serve as a potentially low-technology vector control measure in addition to bednets. With correct education, rural families could be urged to add additional plant materials to the burning firewood or possibly to use mosquito coils. The relatively high costs of the coils in the study area, would plead for the use of burning plant material.

ACKNOWLEDGEMENTS

For scientific guidance and moral support we would especially like to thank the officers in charge: Raymond Paru, Jeffrey Hii, Mike Packer, Julie Abisgold, Martin Cox, Fadwa Al Yaman (Papua New Guinea Institute of Medical Research, Madang) and Willem Takken (Department of Entomology, Wageningen Agricultural University). We gratefully acknowledge the assistance of all technicians from Jeffrey Hii's and Mike Packer's entomology teams and the people from Nale-1 for their co-operation and assistance. For statistical advice we thank the statisticians of IMR-Goroka.

The first two authors conducted this study as a part of their Master of Science biology study. The investigation received financial support by the United States Agency of International Development.

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