COMPARATIVE FIELD EVALUATION OF RESIDUAL-SPRAYED DELTAMETHRIN WG AND DELTAMETHRIN WP FOR THE CONTROL OF MALARIA IN PAHANG, MALAYSIA

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Abstract. The bioefficacy of indoor residual-sprayed deltamethrin wettable granule (WG) formulation at 25 mg a.i./m² and 20 mg a.i./m² for the control of malaria was compared with the current dose of 20 mg/m² deltamethrin wettable powder (WP) in aboriginal settlements in Kuala Lipis, Pahang, Malaysia. The malaria vector has been previously identified as Anopheles maculatus. The assessment period for the 20 mg/m² dosage was six months, but for the 25 mg/m² dosage, the period was 9 months. Collections of mosquitoes using the bare-leg techniques were carried out indoors and outdoors from 7:00 PM to 7:00 AM. All mosquitoes were dissected for sporozoites and parity. Larval collections were carried out at various locations to assess the extent and distribution of breeding of vectors. A high incidence of human feeds was detected during May 2005 and a low incidence during January 2005 for all the study areas. Our study showed that deltamethrin WG at 25 mg/m² suppressed An. maculatus biting activity. More An. maculatus were caught in outdoor landing catches than indoor landing catches for all the study areas. The results indicate that 25 mg/m² WG is good for controlling malaria for up to 9 months. Where residual spraying is envisaged, the usual two spraying cycles per year with 20 mg/m² deltamethrin may be replaced with 25 mg/m² deltamethrin WG every 9 months.

INTRODUCTION

In Malaysia, malaria still remains a public health problem. Although most parts of Peninsular Malaysia are under control, malaria persists in a number of problematic foci, such as in aboriginal areas, tribal villages found in cleared hilly jungles, and in communities working in agricultural and land development. Anopheles maculatus is the principal vector of human malaria in Peninsular Malaysia (Loong et al, 1988; Vythilingam et al, 1995). The degree of epidemicity of malaria is decided by many factors, of which vectorial capacity is one of the most important ones. A knowledge of the behavior and bionomics of the vector species is of vital importance to understand the epidemiological features, to find effective control measures and to interrupt vector-human contact. Several types of insecticides have been used as part of the malaria control measures. At present, chemical control of malaria in Malaysia is carried out using pyrethroid for indoor residual spraying, temephos as a larvicide and permethrin to impregnate bed nets. All these methods are
used to control the Anopheles vectors, such as An. maculatus, An. donaldi, An. balabacensis and others.

Indoor residual spraying of insecticides plays a central role in malaria control programs in Malaysia and several other countries in Southeast Asia and Africa. A reduction in malaria transmission is usually observed after effective residual spraying. Although several insecticides are available for indoor spraying, some have become ineffective because of the emergence of resistance, whereas others, although effective, are not acceptable because of mammalian toxicity or a hazardous effect on the environment. Deltamethrin, a pyrethroid, is frequently and widely used for indoor residual spraying of house surfaces to control anopheline mosquitoes. In Malaysia, deltamethrin wettable powder (WP) has replaced DDT as the main pyrethroid used in residual spraying since 1988. This compound generally is applied in 2 spray rounds per year in malaria-endemic areas (VBDCP, 1988). We have conducted several efficacy and safety trials of new candidate insecticides under the WHO Pesticide Evaluation Scheme. K-Othrine® WG 250, a 25% deltamethrin water dispersible granule formulation, a broad spectrum, fast acting and water-dilutable insecticide for surface application, is being proposed as a new agent for indoor residual spraying.

A comparative field trial of residual spraying with deltamethrin WG and deltamethrin WP was conducted from September 2004 to September 2005 with the main objectives of evaluating the effectiveness of residual spraying of the WG formulation and comparing the effectiveness of this formulation with deltamethrin WP in malaria control. The trial was conducted in Pos Lenjang and Pos Senderot, Kuala Lipis, Pahang. These areas were selected for the study since malaria cases were reported regularly from those villages and entomological investigations had shown a reasonably high density of Anopheles maculatus.

### MATERIALS AND METHODS

**Selection of trial villages**

The settlement was divided into 3 trial areas (Area 1, Area 2 and Area 3) of approximately similar populations and disease incidences. Villages were selected based on available epidemiological records. The inhabitants lived in bamboo huts with attap roofs. The bamboo floors of the houses are usually raised about 0.5 to 1.0 m above the ground. There were 280, 130 and 126 houses in Areas 1, 2 and 3, respectively. Area 1 is in Pos Senderot and Areas 2 and 3 are in Pos Lenjang (Fig 1).

**Trial design**

The houses were sprayed at dosages rate of 20 mg/m² WG in Area 2, 25 mg/m² WG in Area 3, and a comparative dosage of 20 mg/m² WP, which is the currently used dosage for malaria control in Malaysia in Area 1. The first cycle of spraying was conducted 2- 7 August 2004 (Areas 2 and 3) and 7-14 August 2004 (Area 1), after the spray personnel were trained at a workshop. The second spraying was conducted 28 January - 1 February 2005 for Areas 1 and 2. A Hudson® compressor sprayer was used. Use of pyrethroid impregnated bed nets was carried out as usual in the study area.

**Chemical residue analysis**

Filter paper (Whatman No. 3, 15 cm) was pinned on the inner wall before spraying. The sprayers were asked to spray normally, regardless of the presence of the filter paper. The filter papers were removed 30 minutes after spraying to allow them to dry. The filter paper was labeled and packed. Insecticide residue analysis was determined; the results are reported elsewhere.

**Adult survey**

Twelve hour mosquito collections were carried out bi-monthly, overnight from 7:00 PM to 7:00 AM hours with two collectors simultaneously stationed indoors and two outdoors.
All mosquitoes landing on human bait were caught using 50x19 mm glass vials, which were subsequently plugged with cotton wool. Two houses were selected for each village during 2 collection nights for each survey. Captured mosquitoes were identified the following morning and were segregated according to species, village and date. Anopheles species were dissected and examined for infection. Dissections involved first examining the ovaries of each mosquitoes for parity by observing the degree of coiling of the ovarian tracheoles. Midguts and salivary glands of parous mosquitoes were examined for malaria using standard dissection techniques.

Larval survey

Routine larval collections using dippers were carried out at various locations to assess the extent and distribution of breeding sites for An. maculatus. The larvae of other mosquito species found in association with those of An. maculatus were identified and recorded.

Residual effect of insecticide on the wall

A qualitative analysis of residual house spraying was conducted in the study areas. The objective was to determine the insecticide deposits on house surfaces during indoor residual spraying. In each treatment area, 4-6 houses were randomly selected as index houses. The bioassay was conducted following standard WHO techniques for assessing insecticidal deposits on wall surfaces (WHO, 1981). The tests were conducted during the entomological surveys. Exposure chambers consisting of transparent cones with an internal diameter of 8.5 cm and a height of 5.5 cm were used. The cones were affixed onto the
vertically positioned walls using masking tape. Into each cone, 10 to 15 sugar fed, 7-10 day old laboratory-bred females of An. maculatus were released and exposed to the surface for 30 minutes. The cones were covered with black cloth. After exposure, the live mosquitoes were removed and kept for 24 hours to record mortality.

Epidemiological monitoring.

The incidence of malaria in the villages was monitored by bimonthly mass blood surveys (MBS) and the slide positivity rate (SPR) was used to measure the incidence. The MBS was conducted by the local staff and the coverage rate was about 90%.

RESULTS

Spraying and adult survey

This study presents the results of a field evaluation to study the effectiveness of deltamethrin wettable granules (WG) and wettable powder (WP) on the incidence and prevalence of malaria in Kuala Lipis, Pahang. The study was carried out between August 2004 and September 2005. Two spray rounds were completed for Area 1 (20 mg/m² WP) and Area 2 (20 mg/m² WG) in August 2004 and February 2005. Only one spray was carried out for Area 3 (25 mg/m² WG) in August 2004. Results are based on cumulative collection from all the study areas. Adult mosquito collections were made on 42 nights between September 2004 to September 2005. A total of 446 anophelines and 969 Culicines were caught during the survey. The distribution of the mosquitoes in terms of percentages for each study area are shown in Fig 2. Anophelines formed 46.0% of the total catches from 6 entomological surveys conducted during the study period. All Anophelines mosquitoes were dissected for malaria parasites, but no malaria was found in any of the vectors in the three study areas. The mean parous rates were 53.4%, 51.2% and 49.8% for Areas 1, 2 and 3, respectively.

The survey found the presence of the following Anopheles species: An. maculatus, An. donaldi and An. leosphyrus group, and the following Culicine species: Cx. quinquefasciatus, Cx. fusco, Cx. gelidus, Cx. vishnui, Cx.
Residual spraying for malaria control in Pahang, Malaysia

Area 1
Area 2
Area 3

(20 mg/m² WP) (20 mg/m² WG) (20 mg/m² WP)

Fig 5–Indoor collection of An. maculatus per trip in the study areas.

Indoor
Outdoor
Total

Fig 6–Total number of An. maculatus collected per trip in Area 1 (20 mg/m² WP).

Fig 7–Total number of An. maculatus collected per trip in Area 2 (20 mg/m² WG).

An. annulitarsis, Ar. dentatus, Ar. omissus, Ar. flavus, Ar. subalbatus, Ar. magnus, Ar. bhayungi, Ar. digitatus, Ar. dolichcephalus, Armigeres sp, Ma. bonneae, Ma. dives, Ma. uniformis, and Lutzia fascannus.

An. maculatus is the primary vector for malaria in the study area and was the most common Anopheline species collected. Fig 3 shows the seasonal abundance and total numbers of An. maculatus mosquitoes collected per trip. The greatest number collected occurred during May 2005. The greatest outdoor collections during the study period occurred during two peaks: May 2005 (Area 1) and November 2004 (Area 2). The number of species collected outdoor was more evenly distributed in Area 3 (Fig 4). The number of An. maculatus collected indoors showed similar patterns to the study areas (Fig 5).

The numbers of females collected per trip for the different study areas are shown in Figs 6, 7, and 8 for Areas 1, 2 and 3, respectively. The number of An. maculatus collected varied from 4 (September 2004) to 114 (May 2005) in Area 1, from 9 (September 2004) to 55 (November 2004) in Area 2 and from 4 (January 2005) to 41 (May 2005) in Area 3.

An. maculatus first bites were recorded as early as at 7:00 PM. The biting activity of An. maculatus mosquitoes from 7:00 PM to 7:00 PM for each of the study areas is shown in Fig 9. Biting activity peaked at 10:00 PM (Area 2), at 1:00 AM and 3:00 AM in Area 1. Biting activity was lower in Area 3, with several small irregular peaks at 11:00 PM, 1:00 AM and 3:00 AM.

An. maculatus fed outdoors in increasing numbers as the night progressed in Area 1, with the highest peak of feeding from 2:00 AM to 3:00 AM. The feeding activity of An. maculatus started to decrease after 3:00 AM.
An. maculatus fed indoors throughout the night, with two peaks at 10:00 PM and 2:00 AM. Fig 10 shows outdoor biting activity in Area 3 peaked at 10:00 PM. The feeding activity of An. maculatus started to decrease after 10:00 AM until dawn, with a small peak at 3:00 AM. Biting activity indoors was quite low with several irregular peaks. The nocturnal landing and biting activity of An. maculatus is shown in Figs 10 and 11.

Larval surveys

Larval collections were carried out at various locations surrounding the villages and nearby streams. Larvae of An. maculatus and larvae of other mosquitoes were collected, identified and recorded. A total of 33 mosquito breeding sites were identified during the survey. An. maculatus was collected from 14 separate sites and the majority of the sites were partially shaded. Most of the breeding sites were in slow flowing streams with grassy edges. In one instance, larvae were collected from a newly man-made fish pond in Kampong Kenderong (Area 3). More breeding sites with An. maculatus larvae were identified in Area 1. Other mosquito larvae found during the larval survey were An. aitkenii, An. aconitus, Cx. nigropunctatus, Cx. tritaeniorhyncus and Lutzia species.

Residual effects of insecticide on the wall

The results of the residual effects are shown in Figs 12 and 13. Four month-old deposits showed the highest mosquito mortality rate of >90% for the three study areas. The results showed that An. maculatus was susceptible to both the WP and WG formulations. The adult mortality 24 hours after exposure time ranged from 80.0% to 100.0% for all the study areas. Fig 12 sug-
gests a gradually declining mortality rate with progressive age of the spray deposit. Mortality reduced slightly in September and November in Areas 2 and 3, but increased to 100.0% in Mac due to a second spraying in February 2005. Deltamethrin WG at 25 mg/m² exhibited an almost sustained level of effectiveness against An. maculatus until 12 months post-spraying.

The results obtained with the field test of An. maculatus in terms of knock down mortality (KD values) are presented in Fig 13. The KD50 values are defined as the time required to knock down 50% of the mosquitoes in the test. Indoor residual spray in Area 3 (25 mg/m² WG) gave high KD 50 values until 9 months post-spraying.

Epidemiological monitoring

The incidence reported for malaria in the villages is based on cumulative cases. In 2004, Areas 2 and 3 were reported as one monitoring station known as Pos Lenjang and Area 1 as Pos Senderot. Table 1 shows the prevalence of malaria in Pos Lenjang and Pos Senderot, Kuala Lipis. The slide positivity rates (SPR) for Areas 2 and 3 before and after spraying were 0.8-5.9% and 0-0.3%, respectively, whereas the SPR for Area 1 before and after spraying were 0.5-2.0% and 0-0.7%, respectively. Table 2 shows the prevalence of malaria in the study areas for the year 2005. The SPR for Areas 2 and 3 in 2005 were 0-0.45 and 0-0.4, respectively. Area 3 reported two malaria cases in April for the year 2005.

DISCUSSION

This study compared the response of An. maculatus to the standard operational field dose of residual deltamethrin, the approved indoor residual insecticide for malaria control in Malaysia, against different for-
Table 1

<table>
<thead>
<tr>
<th></th>
<th>No. of slides examined</th>
<th>No. positive</th>
<th>SPR (%)</th>
<th>No. of slides examined</th>
<th>No. positive</th>
<th>SPR (%)</th>
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<td>January</td>
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<td>3</td>
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<td>39</td>
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<td>2.6</td>
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<td>February</td>
<td>1,002</td>
<td>20</td>
<td>2.0</td>
<td>808</td>
<td>20</td>
<td>2.5</td>
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<tr>
<td>March</td>
<td>380</td>
<td>2</td>
<td>0.5</td>
<td>219</td>
<td>13</td>
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<tr>
<td>April</td>
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<td>7</td>
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<td>47</td>
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<tr>
<td>May</td>
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<td>0</td>
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<td>4</td>
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<td>1,253</td>
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<td>606</td>
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<td>0</td>
<td>379</td>
<td>13</td>
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<td>August</td>
<td>893</td>
<td>2</td>
<td>0.2</td>
<td>513</td>
<td>2</td>
<td>0.4</td>
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<td>September</td>
<td>1,257</td>
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<td>1,214</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
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<td>0.2</td>
<td>1,286</td>
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<tr>
<td>November</td>
<td>886</td>
<td>6</td>
<td>0.7</td>
<td>612</td>
<td>1</td>
<td>0.2</td>
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<tr>
<td>December</td>
<td>1,265</td>
<td>2</td>
<td>0.1</td>
<td>1,141</td>
<td>1</td>
<td>0.09</td>
</tr>
</tbody>
</table>

SPR - Slide positivity rate; First spraying - August 2004; Second spraying - February 2005

Table 2
Prevalence of malaria in Area 1, Area 2 and Area 3, 2005.

<table>
<thead>
<tr>
<th></th>
<th>Area 1 (20 mg/m² WP)</th>
<th>Area 2 (20 mg/m² WG)</th>
<th>Area 3 (25 mg/m² WG)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of slides examined</td>
<td>No. positive</td>
<td>SPR (%)</td>
</tr>
<tr>
<td>January</td>
<td>352</td>
<td>0</td>
<td>0</td>
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<tr>
<td>February</td>
<td>921</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>March</td>
<td>217</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>April</td>
<td>1,064</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>May</td>
<td>578</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Jun</td>
<td>1,122</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>July</td>
<td>232</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>August</td>
<td>1,168</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>September</td>
<td>356</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

SPR - Slide positivity rate; First spraying - August 2004; Second spraying - February 2005

Both wettable granules (WG) and wettable powder (WP) formulations were very effective against indoor resting anophelines and reduced malaria cases by 90 to 100%. The slide positivity rates for all the study areas were low after residual spraying. Rowland et al. (2000) reported that suspension concentrate and wettable powder of alphacypermethrin reduced falciparum malaria by 95% and vivax malaria by 88%.

The study areas are aboriginal resettlement areas, and are carved out of a secondary forest situated on hilly terrain, with most villages being riverine. The vegetation of the areas consists of tall grasses, shrubs, patches of rubber trees of different varieties and hill-
The houses are scattered about the area, usually in the clearings of the foothills. Clearing of jungle cover for cultivation might contribute to suitable breeding habitats for An. maculatus. The larvae were found in stream margins, ditches and seepages. These were normally fresh, shallow water habitats, slow flowing, usually with emergent vegetation and partially exposed to sunlight. Rahman et al (1992) reported that the opening of land for rubber plantations surrounding Kampong Bogor, Hulu Perak has produced serious outbreaks of malaria.

Control of An. maculatus mosquitoes by indoor residual spraying is an appropriate strategy because mosquitoes, such as An. maculatus, do enter and rest in treated houses and have sufficient contact with sprayed surfaces before and after biting humans (Loong et al, 1988). The results of this study demonstrate that deltamethrin spray deposits were effective in killing malaria vectors up to 6 months post-spray in Areas 1 and 2. Both the bioassay tests and the mortality figures showed that deltamethrin WG at 25 mg/m$^2$ was effective for a period of up to 9 months.

The study showed that An. maculatus was the predominant man biting mosquito in these arborigines villages. A peak incidence of human biting was detected in May 2005 and a low incidence during January 2005 for all the study areas. The results show that no significant differences in terms of densities and seasonal trends for the vector mosquitoes among the treatment areas. Our study showed that 25 mg/m$^2$ WG indoor residual spray reduced An. maculatus biting activities as shown in Fig 9. More An. maculatus were caught in Areas 1 and 2 than Area 3, and more An. maculatus was caught in outdoor landing catches than indoor landing catches for all the study areas.

Biting was the most important activity examined. The data obtained from man biting catches outdoors and indoors were analyzed to understand the biting cycle of the vector species. Biting of An. maculatus occurred throughout the night in all study areas. Loong et al (1988) and Vythilingam et al (1995) established that An.maculatus bites both indoors and outdoors. Similar findings were observed in this study. All the study results showed that An. maculatus fed more actively from 10:00 PM to 3:00 AM. An. maculatus contacted humans most frequently, with a maximum of 4.5 bites per human per night, in Area 1. Biting activity peaked during the first quarter of the night in Areas 2 and 3, but after midnight in Area 1. An. maculatus bites per man-night were reduced when 25 mg/m$^2$ WG was introduced into the villages in Area 3.

The principal objective of control is to prevent vector-human contact by killing mosquitoes and/or reducing the longevity of the vector mosquitoes. In Malaysia, the vectors are endophilic (Loong et al, 1988; Vythilingam et al, 1995). Based on this finding, indoor residual spraying with a long-lasting insecticide is the classical method of mosquito control. Indoor residual application can be effective provided the spray is complete and correct dosages are used. The results presented here indicate that 25 mg/m$^2$ WG is a good method for controlling malaria vectors. Where residual spraying is envisaged, the usual two spraying cycles per year with a dosage of 20 mg/m$^2$ may be reduced every 9 months because the residual activity of the 25 mg/m$^2$ WG deposits lasts about one year. Thus, an increase in the quality and coverage of spraying may be achieved. This study proved that residual spraying is a good method for malaria control. The study also suggests total elimination of malaria in Malaysia is now possible.

ACKNOWLEDGEMENTS

We especially thank the Kuantan and Kuala Lipis Vector Control Unit and Medical Entomology Unit of IMR, without whose
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REFERENCES


