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. /m^2 and 20 mg a.i./m^2 for the control of malaria was compared with the current dose of 20 mg/m^2 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/m^2 dosage was six months, but for the 25 mg/m^2 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/m^2 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/m^2 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/m^2 deltamethrin may be replaced with 25 mg/m^2 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

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used to control the *Anopheles* vectors, such as *An. maculatus, An. donaldi, An. balabaciensis* 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 efectiveness 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/m^2 WG in Area 2, 25 mg/m^2 WG in Area 3, and a comparative dosage of 20 mg/m^2 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.

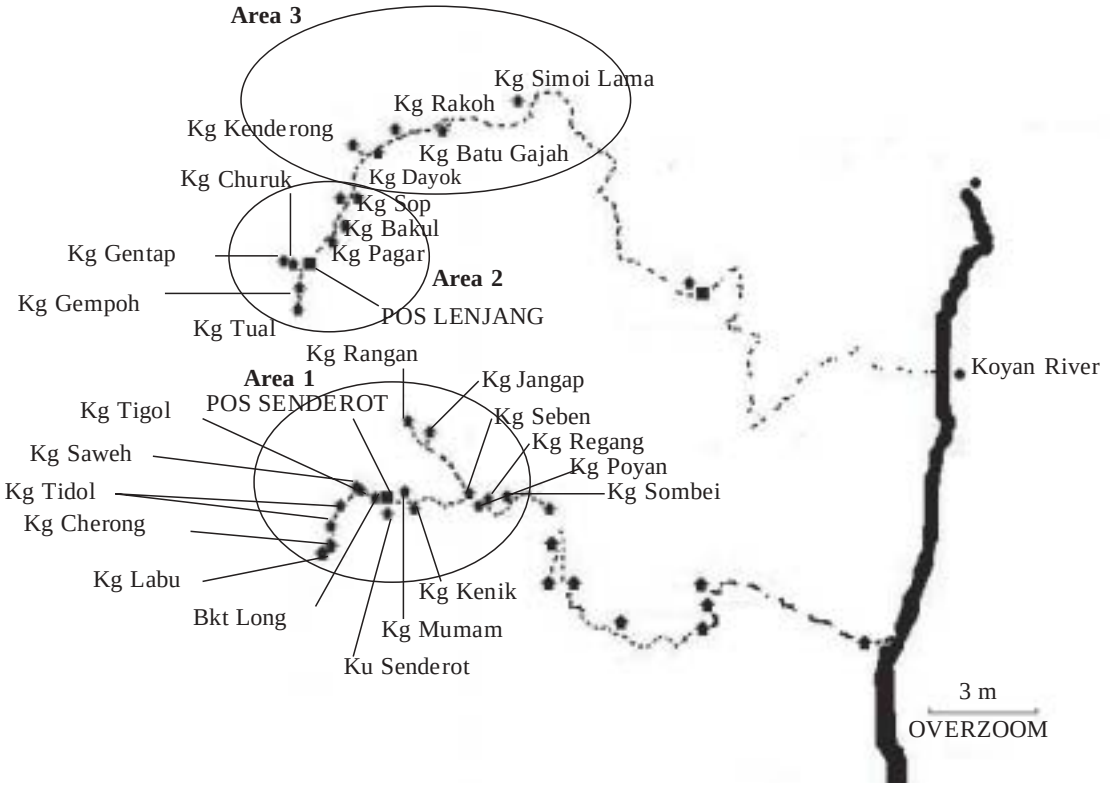


Fig 1–Map of study sites in Kuala Lipis, Pahang.

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/m^2 WP) and Area 2 (20 mg/m^2 WG) in August 2004 and Febuary 2005. Only one spray was carried out for Area 3 (25 mg/m^2 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. *Anopheles* formed 46.0% of the total catches from 6 entomological suveys conducted during the study period. All *Anopheles* 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.

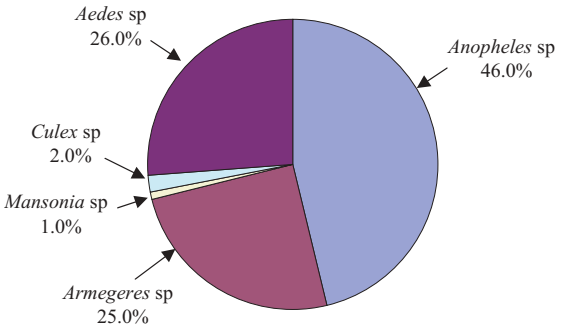


Fig 2–Distribution of mosquitoes (percentage) in the study areas.

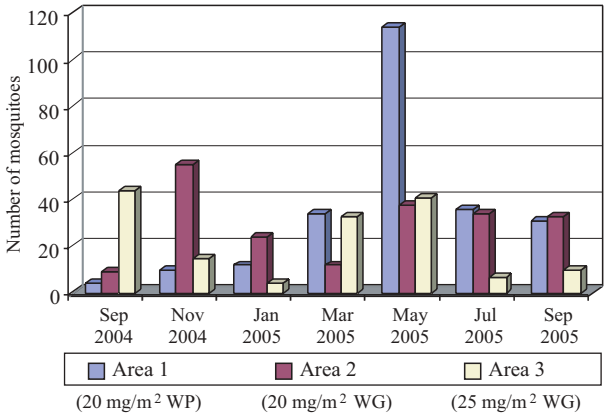


Fig 3–Total number of *An. maculatus* collected per trip.

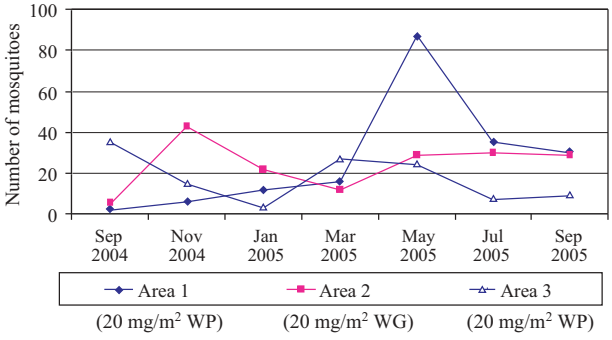


Fig 4–Outdoor collection of *An. maculatus* per trip in the study areas.

The survey found the presence of the following Anopheline species: *An. maculatus, An. donaldi* and *An. leosphyrus* group, and the following Culicine species: *Cx. quinquefasciatus, Cx. fusco, Cx. gelidus, Cx. vishnui, Cx.*

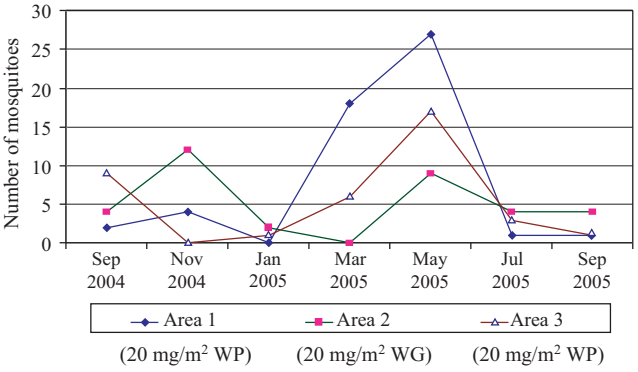


Fig 5–Indoor collection of *An. maculatus* per trip in the study areas.

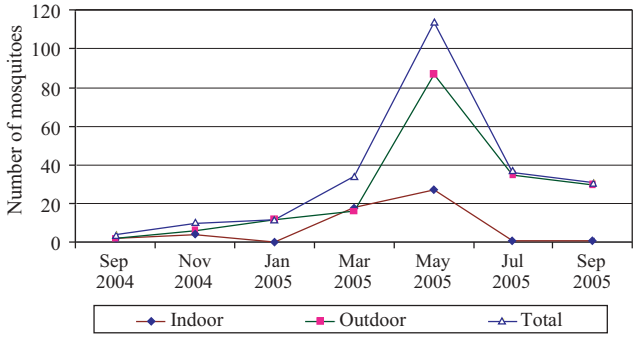


Fig 6–Total number of *An. maculatus* collected per trip in Area 1 (20 mg/m^2 WP).

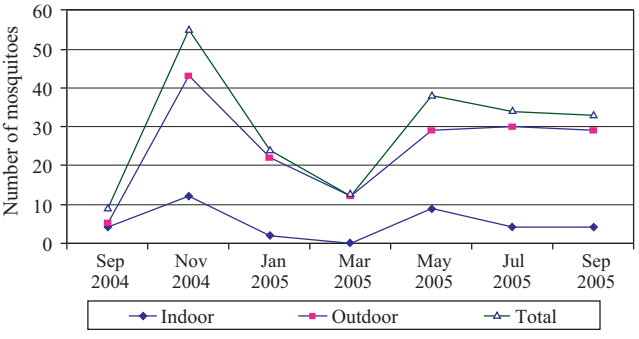


Fig 7–Total number of *An. maculatus* collected per trip in Area 2 (20 mg/m^2 WG).

bitaeniorhyncus, Cx. tritaeniorhyncus, Cx pseudovishnui. The other species found were: *Aedes albopictus, Ae. chrysolineatus, Ae. desmates, Ae. niveus* gp, *Ae. vexans, Ae. pseudoalbopictus, Aedes* sp, *Armigeres kaselli, Ar. annulitarsis, Ar. dentatus, Ar. omissus, Ar. flavus, Ar. subalbatus, Ar. magnus, Ar. bhayungi, Ar. digitatus, Ar. dolichocephalus, 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 varried 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

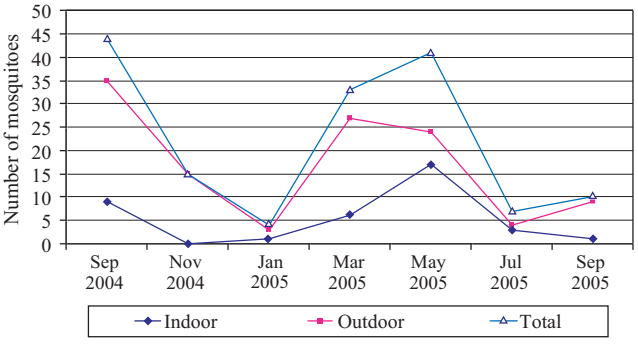


Fig 8–Total number of *An. maculatus* collected per trip in Area 3 (25 mg/m^2 WG).

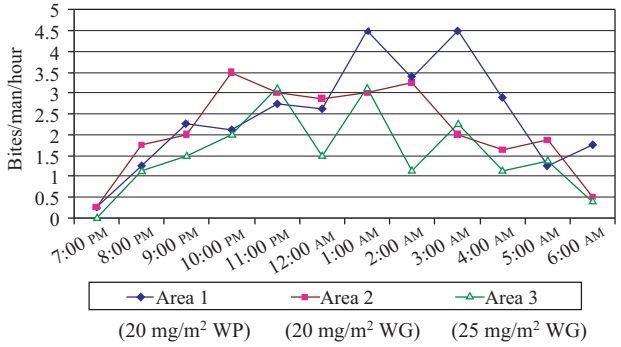


Fig 9–Biting activity of *An. maculatus* in the study areas.

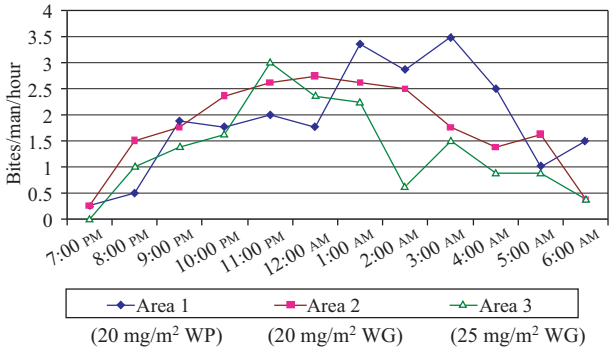


Fig 10–Outdoor biting activity of *An. maculatus* in the study areas.

until dawn, with a small peak at 6:00 AM. *An. maculatus* fed indoors all through the night with several small irregular peaks. In Area 2, *An. maculatus* biting outdoors occurred quite early, with the highest biting activity at 10:00 PM to 2:00 AM. Feeding activity diminished after 2:00 AM with one small peak at 5:00 PM.

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 seperate 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-

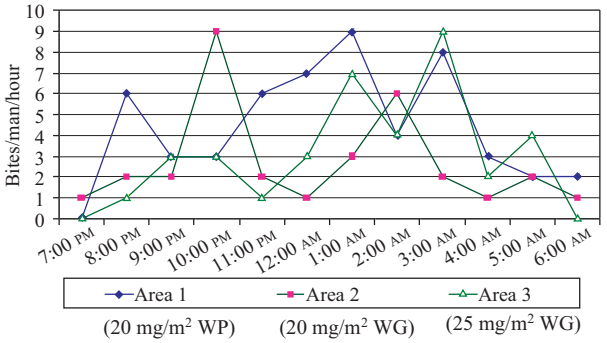
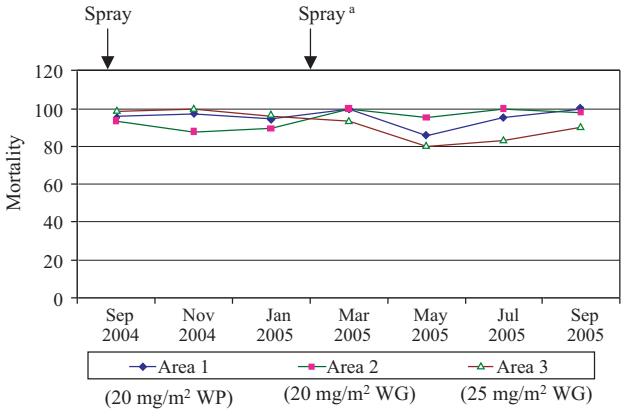
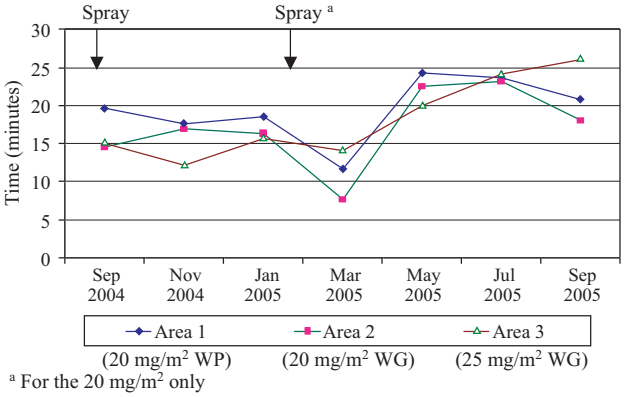


Fig 11– Indoor biting activity of *An. maculatus* in the study areas.



a For the 20 mg/m^2 only

Fig 12–Percentage mortality of *An. maculatus* after 24 hour exposure time.



a For the 20 mg/m^2 only

Fig 13–KD50 value (minutes) of deltamethrin against *An. maculatus*.

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/m^2 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/m^2 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 prevalance 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 prevalance 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
Prevalence of malaria in Pos Lenjang and Pos Senderot, 2004.

	Pos Senderot (Area 1)			Pos Lenjang (Area 2 and 3)		
	No. of slides examined	No. positive	SPR (%)	No. of slides examined	No. positive	SPR (%)
January	276	3	1.1	39	1	2.6
February	1,002	20	2.0	808	20	2.5
March	380	2	0.5	219	13	5.9
April	1,031	7	0.7	1,154	47	4.1
May	422	0	0	340	4	1.2
Jun	1,276	0	0	1,253	10	0.8
July	606	0	0	379	13	3.4
August	893	2	0.2	513	2	0.4
September	1,257	0	0	1,214	3	0.3
October	544	1	0.2	1,286	0	0
November	886	6	0.7	612	1	0.2
December	1,265	2	0.1	1,141	1	0.09

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.

	Area 1 (20 mg/m^2 WP)			Area 2 (20 mg/m^2 WG)			Area 3 (25 mg/m^2 WG)		
	No. of slides examined	No. positive	SPR (%)	No. of slides examined	No. positive	SPR (%)	No. of slides examined	No. positive	SPR (%)
January	352	0	0	196	0	0	233	0	0
February	921	0	0	492	0	0	362	0	0
March	217	0	0	263	0	0	292	0	0
April	1,064	0	0	663	3	0.45	496	2	0.4
May	578	0	0	302	0	0	297	0	0
Jun	1,122	0	0	634	2	0.32	555	0	0
July	232	0	0	310	1	0.32	159	0	0
August	1,168	0	0	683	0	0	411	0	0
September	356	0	0	330	1	0.3	296	0	0

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

mulations and higher dosages of deltamethrin. 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 posivity rates for all the study areas were low after residual sparaying. 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-

padi. 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 mosquitos 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

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