Advances in Entomology, 2014, 2, 151-160
Published Online July 2014 in SciRes. http://www.scirp.org/journal/ae
http://dx.doi.org/10.4236/ae.2014.23023

Impact of Indoor Residual-Sprayed Deltamethrin on Different Surfaces in a Malaria Endemic Area in Balai Ringin, Sarawak

Ahmad Rohani[1*], Ismail Zamree[1], Wan Najdah Wan Mohamad Ali[1], Azahari Abdul Hadi[1], Matusop Asmad[2], Zurainee Mohamed Nor[3], Lee Han Lim[1]

[1]Medical Entomology Unit, Infectious Disease Research Center, Institute for Medical Research, Kuala Lumpur, Malaysia
[2]Vector Borne Disease Control Programme, Sarawak State Health Department, Kuching, Malaysia
[3]Department of Parasitology, Faculty of Medicine, University of Malaya, Kuala Lumpur, Malaysia
Email: [*]rohania@imr.gov.my

Received 31 March 2014; revised 7 May 2014; accepted 17 June 2014

Abstract

Malaria control programme utilizing indoor residual spraying of chemical insecticide is only effective if a high coverage of targeted area is achieved. The effectiveness of the residual spraying, on the other hand, relies on the efficacy and residual activity of the insecticides applied, which to a certain extent are influenced by the nature of the sprayed surfaces. The bioefficacy of indoor residual-sprayed deltamethrin wettable granule (WG) formulation for the control of malaria was compared with the current dose of deltamethrin wettable powder (WP) in malaria endemic areas in Balai Ringin, Sarawak. Doses of 20 mg/m² WP (control), 20 mg/m² WG, 30 mg/m² WG and 40 mg/m² WG were sprayed separately on different surfaces namely, wooden, rough-bamboo, smooth-bamboo and brick surfaces. Residual activity of WP and WG formulations was tested against lab-bred *Anopheles maculatus* using WHO standard procedure. Deltamethrin at 30 mg/m² WG exhibited the highest sustainable level of effectiveness against *An. maculatus* (*An. maculatus* mortality was between 95% - 100%) up to week 60 post-spraying when sprayed on smooth-bamboo surface. These results indicated that 30 mg/m² WG could be an ideal concentration for controlling malaria vector effectively up to 15 months of which long-lasting residual spraying was envisaged. The usual two spraying cycles per year with 20 mg/m² deltamethrin WP could be replaced with 30 mg/m² deltamethrin WG since the long residual activity was achieved by employing a single spraying only.

[*]Corresponding author.

How to cite this paper: Rohani, A., Zamree, I., Ali, W.N.W.M., Hadi, A.A., Asmad, M., Nor, Z.M. and Lim, L.H. (2014) Impact of Indoor Residual-Sprayed Deltamethrin on Different Surfaces in a Malaria Endemic Area in Balai Ringin, Sarawak. *Advances in Entomology*, **2**, 151-160. http://dx.doi.org/10.4236/ae.2014.23023

Keywords

Component, Indoor Residual-Sprayed, Deltamethrin, Wettable Granule, *An. maculatus*

1. Introduction

Indoor residual spraying of insecticides plays a central role in malaria control programme in Malaysia and in several other countries in Southeast Asia and Africa. A reduction in malaria transmission is usually observed after effective residual spraying operations. Although several insecticides are available for indoor spraying, some of these have become ineffective due to the emergence of resistance, while others, though their effectiveness were maintained, they are no longer accepted due to their high mammalian toxicity or hazardous persistence in the environment.

Indoor residual spraying of pyrethroids is still the principal method of vector control in Malaysia. Since 1998, deltamethrin WP has replaced DDT as the main pyrethroid used in residual spraying. This compound is generally applied in two spray rounds per year in malaria endemic areas. Malaria control programmes utilizing indoor residual spraying are only effective if a high coverage of targeted area is achieved and an effective insecticide is correctly applied [1].

The residual life span and efficacy of most insecticides are affected by the chemical nature of the sprayed surfaces [2]. Therefore, the residual efficacy and the persistence of insecticide may vary on different types of surface material used in the construction of houses in the aborigine areas or traditional villages in Malaysia. The degree of epidemicity of malaria on the other hand, is depended upon many factors, of which vectorial capacity is one of the most important factors. The knowledge of behaviour and bionomics of vector species is of vital importance in understanding the epidemiological features, in order to determine the most effective control measures and to interrupt vector-human contact.

Knowing the longevity of the individual residual insecticide activity after each spraying is in fact useful for the purpose of vector control, it provides information for the minimum interval required between spraying in order to maintain the resistance of the insecticide so that the human population remains protected until the next spraying round is conducted. A good residual spraying should be long lasting on a given surface, such that any mosquito coming in contact will get a lethal dose and die. Therefore, the transmission of malaria is interrupted [3]. The insecticide toxicity should also remain high over a sufficiently long period to prevent the need for frequent re-application, which is costly and time-consuming.

In Malaysia, malaria persists in a number of problematic foci such as in the arboriginal area and other tribal villages found in cleared hilly jungles, and in communities working in agricultural and land development scheme. These settlements are often deep in the forest, difficult to get access and pose a tremendous logistic difficulty and financial burden in implementing sustainable control activities.

The vectors found in Malaysia are endophilic [4] and therefore indoor residual application can be effective provided that the spray is complete and correct dosages are used. Based on this finding, indoor residual spray with a long-lasting insecticide has the potential to become an important methodology for adult mosquito control and is definitely useful for malaria vector control in highly remote areas.

Therefore, it is desirable to determine the residual efficacy of deltamethrin against *Anopheles* mosquitoes on various surfaces and to determine the required dose of deltamethrin for single round spraying in order to provide sufficient protection in rural areas of Balai Ringin, Sarawak.

2. Materials and Methods

2.1. Study Area

The study was conducted in Balai Ringin, Serian, Sarawak (01˚00.161'N 110˚48.007'E and 1.1667'N 110.5567'E). The study site comprised of several villages and was selected based on its accessibility, severity and high frequency of malaria epidemics and outbreaks that had been reported previously [5]. The houses in the villages consisted of individual, link and long houses and were built using various materials including wood, bamboo and brick. Thus, provide the opportunity to assess the effect of each surface on the availability and per-

sistence of insecticide over time. The field evaluation was carried out in four villages: 1) Danau Karangas Baru, 2) Danau Melikin, 3) Melikin Lama and 4) Danau Karangas Lama. Selection of villages was done in consultation with state health malaria programme personnel. There were 24, 46, 17 and 31 houses in Danau Karangas Baru, Danau Melikin, Melikin Lama and Danau Karangas Lama respectively. Currently the villages received two rounds of deltamethrin WP spraying under the Malaria Control Programme and *An. letifer* is well known to be the primary vector of malaria in Sarawak [6].

2.2. Trial Design

Deltamethrin WG (Wettable Granule) available under trade name K-Othrine WG 25™ was supplied by Bayer Environmental Sciences, Co. Spraying in the experimental and control villages was carried out as per the schedules of spray recommended by the State Health Department by using techniques and equipment used in routine vector control programme. Supervision of the spraying was also assisted by the State Health Department. All personnel involved in spraying in this study were previously trained in a workshop.

The internal walls of the houses in Danau Karangas Baru were sprayed with 20 mg/m^2 WG, in Danau Melikin with 30 mg/m^2 WG, in Melikin Lama with 40 mg/m^2 WG, and in Danau Karangas Lama (control village) with 20 mg/m^2 WP (the current dosage used for malaria control in Malaysia). Inhabitants were informed of the spraying a day in advance. Necessary precautions were taken for the protection of spray personnel by providing protective clothing, goggles, gloves, etc. The use of pyrethroid impregnated bed nets was carried out as usual in the study areas.

The first cycle of spraying was conducted in August 2009 for all the study villages, while the second spraying was conducted in March 2010 for Danau Karangas Lama (20 mg/m^2 WP), and Danau Karangas Baru (20 mg/m^2 WG) only. All the dwellings, namely human dwellings, mixed dwellings, temporary sheds and other structures were sprayed.

2.3. Insecticide Susceptibility Tests

Persistence of residual efficacy of insecticide spray in the study villages was assessed using standard WHO bioassay cone techniques [7]. These bioassays were carried out every six weeks in all the study villages. In each study village, 6 - 9 houses were randomly selected as index houses. Residual activity was determined on different wall surfaces available in the study villages, viz. thatched bamboo (smooth and rough surfaces) and wood and brick surfaces. 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 days old laboratory-bred females of *An. maculatus* were released and exposed to the surface for 30 minutes. The cones were covered with black cloth during the exposure time. During this time, the cumulative number of mosquitoes knocked down was recorded every 3 minutes for 30 minutes. After the exposure, all mosquitoes were transferred into paper cups covered with netting. Cotton pads soaked with 10% sugar solution and Vitamin B complex solution (1%) were placed on the nettings of the cups. Final mortality was further recorded after 24 hours of holding period.

2.4. Data Analysis

Percentage mortality was corrected using Abbot's formula. Log-time probit mortality regression and knock down time (KD50) values for each treatment were calculated using the computer program "Probit Analysis" (Quant) modified by Finney [8]. KD50 values for adult mosquito represents the time required to knock down 50% of test mosquitoes. All the data were entered in MS Excel and statistically analysed using SPSS v. 10.0 (SPSS Inc. Chicago, USA). Comparisons of survival rates, paired by insecticide dosages and type of surfaces were performed using Friedman test to establish the significance level at 5%.

The first round of deltamethrin spray was carried out in August 2009 in Danau Karangas Baru (20 mg/m^2 WG), Danau Melikin (30 mg/m^2 WG), Melikin Lama (40 mg/m^2 WG) and Danau Karangas Lama (20 mg/m^2 WP). A total of 118 human dwellings were sprayed in the first round with 98.3% house coverage. The second round of spraying conducted in March 2010 had 54 houses sprayed in Danau Karangas Baru and Danau Karangas Lama with 98.2% coverage. Entomological studies and insecticide bioassay were conducted every six weeks in all the study villages for a period of 15 months post spraying.

3. Results

3.1. Spraying and Adult Survey

The first round of deltamethrin spray was carried out in August 2009 in Danau Karangas Baru (20 mg/m^2 WG), Danau Melikin (30 mg/m^2 WG), Melikin Lama (40 mg/m^2 WG) and Danau Karangas Lama (20 mg/m^2 WP). A total of 118 human dwellings were sprayed in the first round with 98.3% house coverage. The second round of spraying conducted in March 2010 had 54 houses sprayed in Danau Karangas Baru and Danau Karangas Lama with 98.2% coverage. Entomological studies and insecticide bioassay were conducted every six weeks in all the study villages for a period of 15 months post spraying.

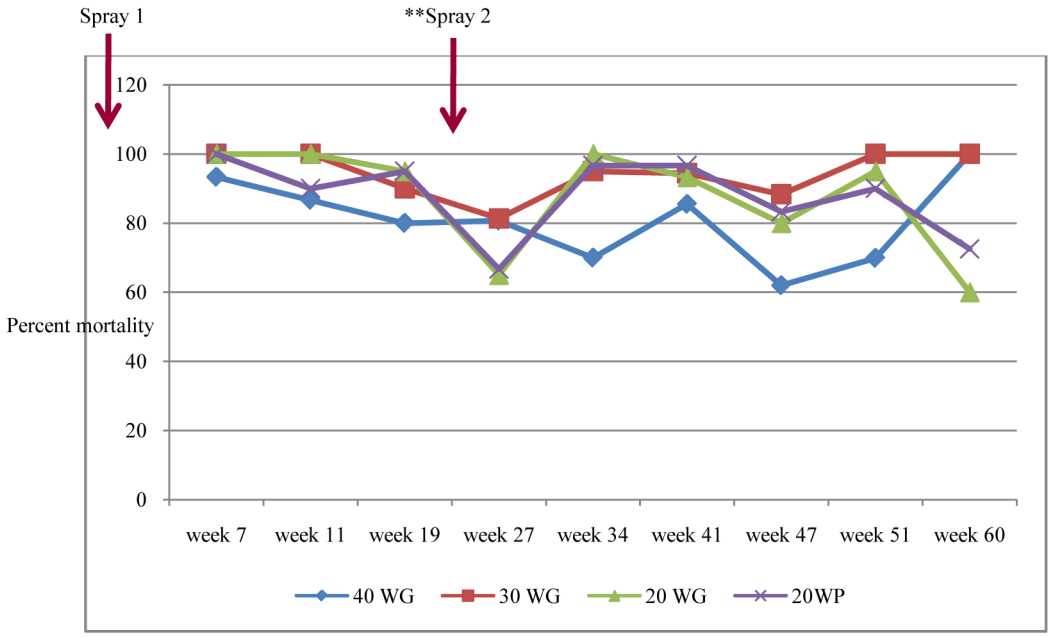
3.2. Residual Effects of Insecticide on the Wall

In this study, *An. maculatus* laboratory strain was used for the purpose of adult bioassay test replacing *An. letifer* which is the primary vector for malaria in the study area. The replacement was due to the unavailability of laboratory strain of *An. letifer* and the insufficient number collected. The following figures demonstrated *An. maculatus* mortality after 24 hours recovery period in successive weeks, when exposed to different concentrations of deltamethrin on wooden surface (**Figure 1**), rough-bamboo surface (**Figure 2**), smooth-bamboo surface (**Figure 3**) and brick surface (**Figure 4**).

Deltamethrin sprayed on wooden surface at 30 mg/m^2 WG maintained its level of effectiveness against *An. maculatus* up to week 60 post spraying with mortality ranging between 80% - 100%. As for other concentrations, although its effectiveness against *An. maculatus* up to week 60 were maintained, results showed that the level of effectiveness was reduced as indicated by lower mortality of between 60% - 100% (**Figure 1**).

Deltamethrin sprayed on rough-bamboo surface at 30 mg/m^2 WG also maintained its level of effectiveness against *An. maculatus* up to week 60 post spraying with mortality ranging between 80% - 100%. This result clearly demonstrated that *An. maculatus* was actually susceptible to both, WP and WG formulations. Other concentrations also maintained its level of effectiveness up to week 60 post spraying but were slightly less effective as shown by mortality of 70% - 100% (**Figure 2**).

Deltamethrin sprayed on smooth-bamboo surface at 30 mg/m^2 WG maintained its level of effectiveness against *An. maculatus* up to week 60 post spraying at its best with mortality kept at as high as 95% - 100%. Other concentrations applied (40 mg/m^2 WG and 20 mg/m^2 WP), were slightly less effective with *An. maculatus* mor-



** Spray 2 - for the 20 mg/m^2 dosage only

Figure 1. Percentage mortality of *An. maculatus* deltamethrin sprayed wood surfaces.

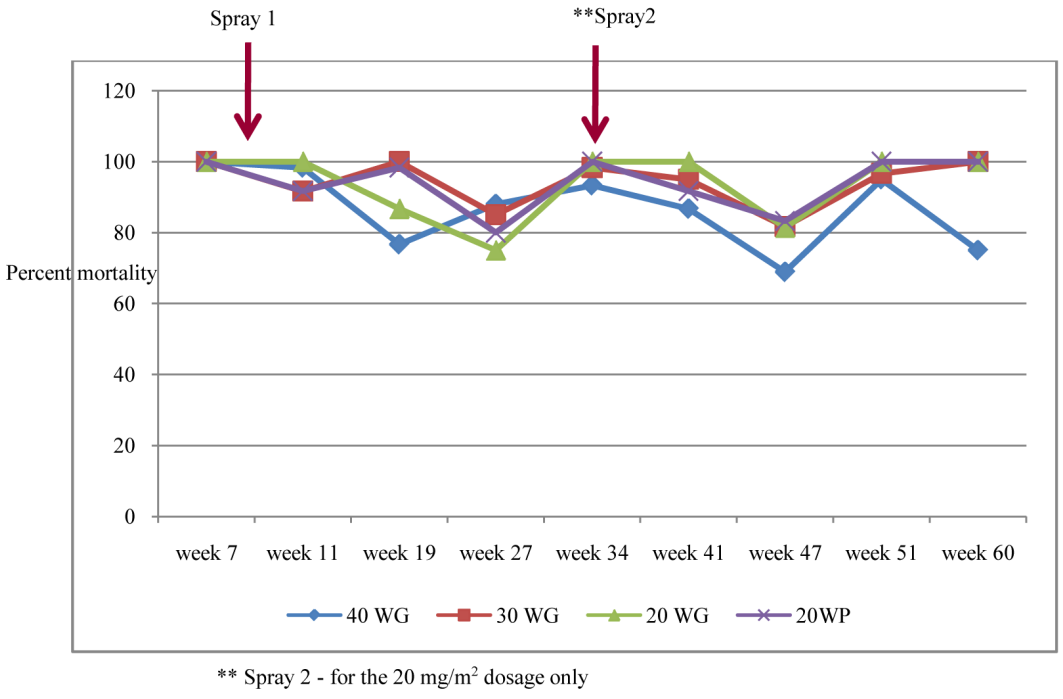


Figure 2. Percentage mortality of *An. maculatus* deltamethrin sprayed bamboo rough surfaces.

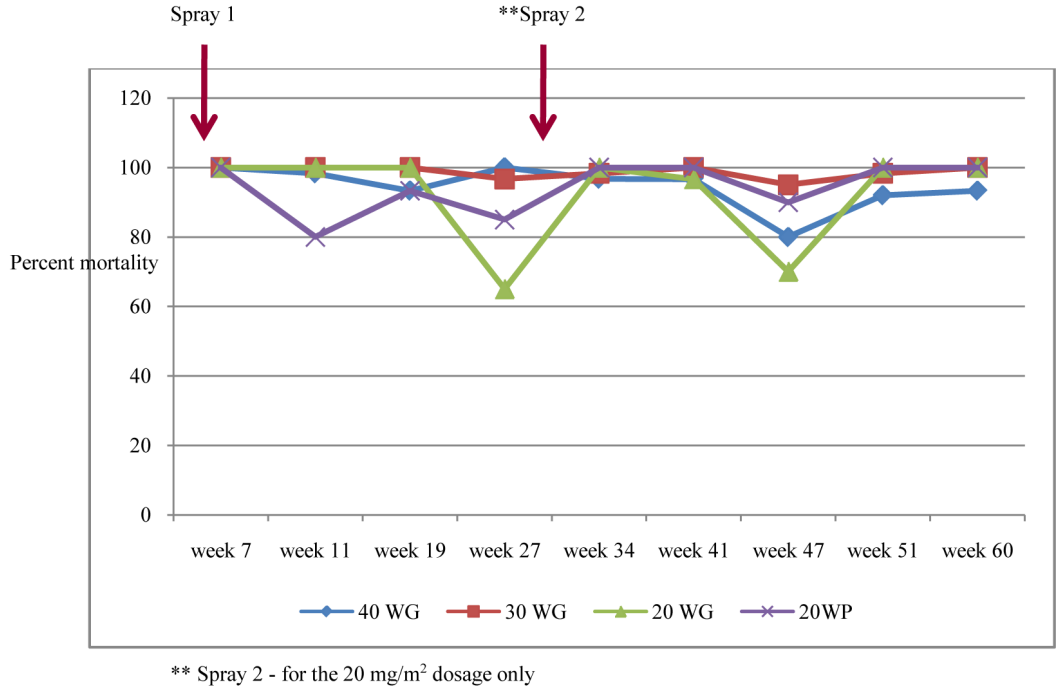
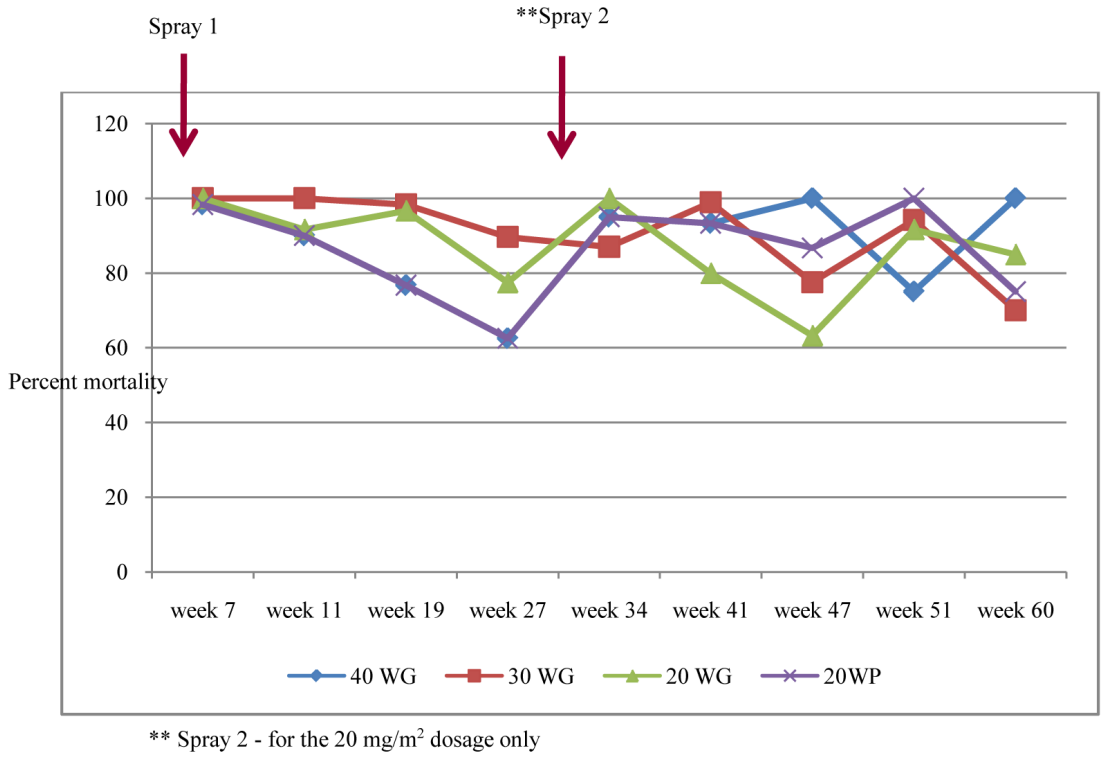


Figure 3. Percentage mortality of *An. maculatus* deltamethrin sprayed bamboo smoothsurfaces.

tality between 80% - 100%, while at 20 mg/m^2 WG, the mortality dropped even lower to between 60% - 100% (**Figure 3**).

Deltamethrin sprayed on brick surface at 30 mg/m^2 WG was also found to maintain its level of effectiveness against *An. maculatus* up to week 60 post spraying but with mortality ranging between 70% - 100%. Other concentrations applied were even less effective with mortality between 60% - 100% (**Figure 4**).



** Spray 2 - for the 20 mg/m^2 dosage only

Figure 4. Percentage mortality of *An. maculatus* deltamethrin sprayed brick wall surfaces.

These results indicated that deltamethrin when employed at 30 mg/m^2 WG and sprayed on all types of surfaces, worked at its best in causing high mortality of *An. maculates* compared to other concentrations and its effectiveness lasted the longest when sprayed on smooth-bamboo surface causing between 95% - 100% *An. maculatus* mortality up to week 60 post spraying. The toxicity of deltamethrin applied at 30 mg/m^2 WG on different surface materials based on mean *An. maculatus* mortality could be summarised in the following descending order: smooth-bamboo > rough-bamboo > wooden > brick surfaces. However, no significant different were observed between the treated surfaces ($\chi^2 = 6.529$, $p > 0.05$).

The following figures demonstrated variations of knockdown values (KD50) of *An. maculatus* after contact with wooden surface (**Figure 5**), rough-bamboo surface (**Figure 6**), smooth-bamboo surface (**Figure 7**) and brick surface (**Figure 8**) sprayed with different concentrations of deltamethrin (40 mg/m^2 WG, 30 mg/m^2 WG, 20 mg/m^2 WG and 20 mg/m^2 WP) recorded up to week 60 post spraying. The shortest KD50 value (15 min and below) was achieved when deltamethrin was used at 30 mg/m^2 WG and 20 mg/m^2 WG, while a KD50 value of 16 - 18 min were achieved when 40 mg/m^2 WG and 20 mg/m^2 WP deltamethrin were used. These KD50 values were recorded when deltamethrin were sprayed on both types of bamboo surfaces. Similar concentrations employed on wooden and brick surfaces, however, presented KD50 values above 22 minutes.

4. Discussion

A village-scale study was conducted to compare the response of *An. maculatus* at different formulations and higher dosages of deltamethrin to the standard operational field dose of residual deltamethrin; the approved indoor residual insecticide for malaria control in Malaysia. This study has clearly shown that the residual efficacy of deltamethrin varied when sprayed on different type of surfaces even though the same dose of deltamethrin was used. This indicates that the residual effect of deltamethrin is affected by the nature of the sprayed surfaces. Some surfaces which do not absorb insecticide particles presented longer duration of residual effect, while others that absorbed the insecticide resulted on having a shorter duration of residual effect. Various surfaces such as wooden, rough-bamboo, smooth-bamboo and brick surfaces were examined in the present study. Our study showed that the smooth-bamboo surface produced the longest duration of the residual effect followed by rough-bamboo, wood and brick surfaces. However, all the concentrations tested in the study showed lower and

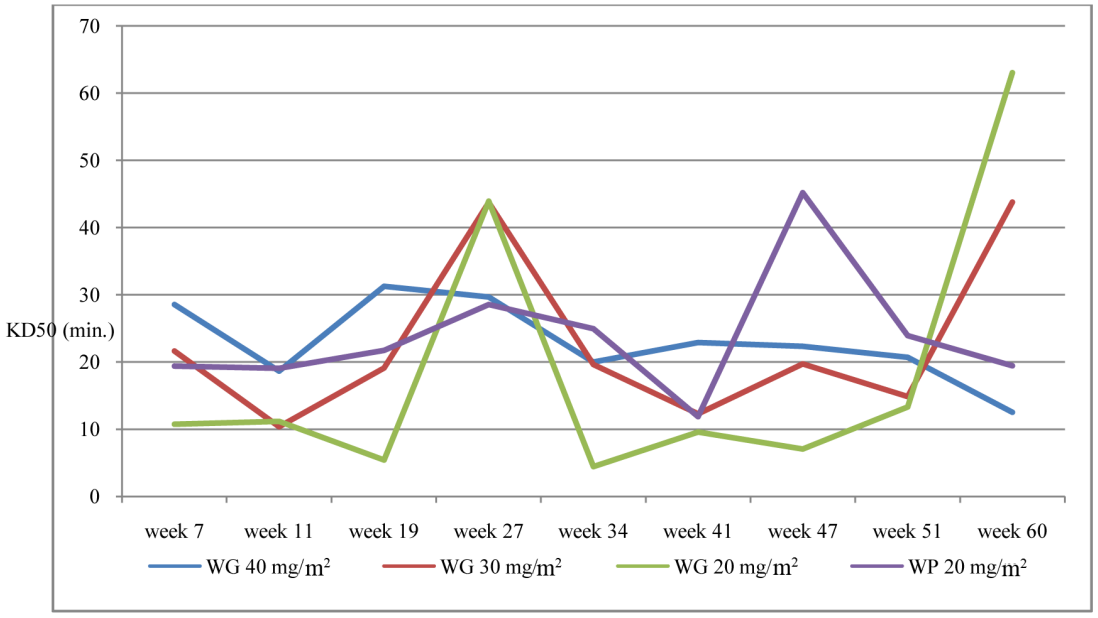


Figure 5. KD50 value (minute) of deltamethrin against *An. maculatus* sprayed wood surfaces.

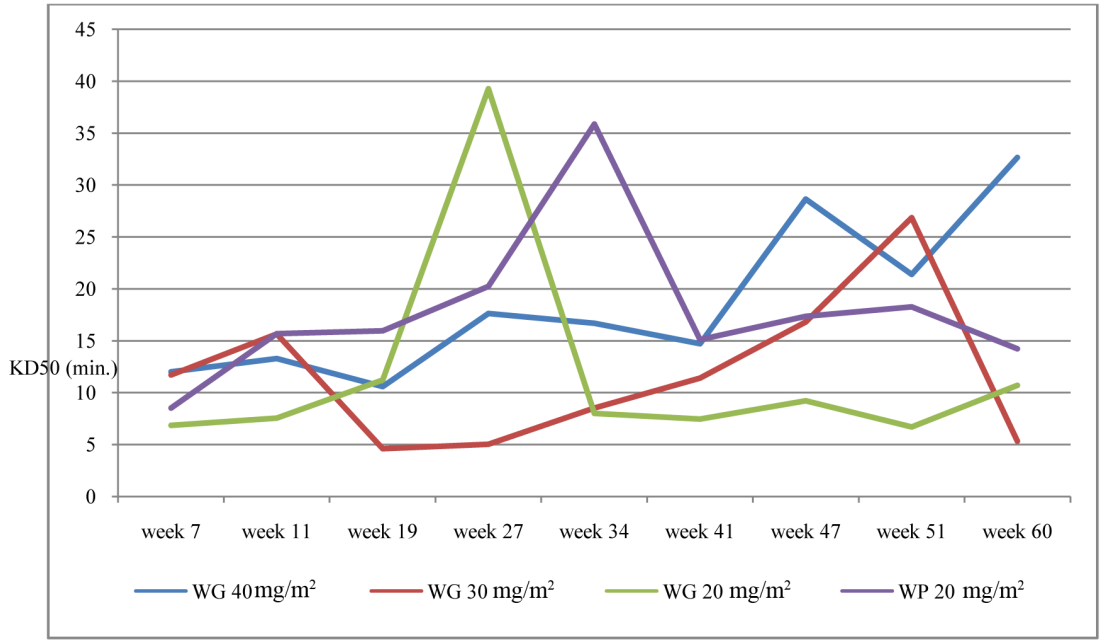


Figure 6. KD50 value (minute) of deltamethrin against *An. maculatus* sprayed smooth-bamboo surfaces.

very variable effect when deltamethrin was applied to the brick surfaces. One of the main reasons for the loss of deltamethrin activity is the fast absorption by porous surfaces. Brick surfaces are porous and may degrade the molecule of the insecticide faster [9].

The residual effect of deltamethrin was also shown to be influenced by the rate of application (concentration) where the effect was at its best when 30 mg/m^2 WG was applied compared to 20 mg/m^2 WG. The fact that the residual effect was not improved when the dose was increased to 40 mg/m^2 WG indicated that a threshold level of the dose is required for maximum effect beyond which efficacy is not affected anymore once the rate of application is above the threshold. The study also observed that mortality test on surfaces after a second application always gave higher results than those noted after the first application. This phenomenon could be demon-

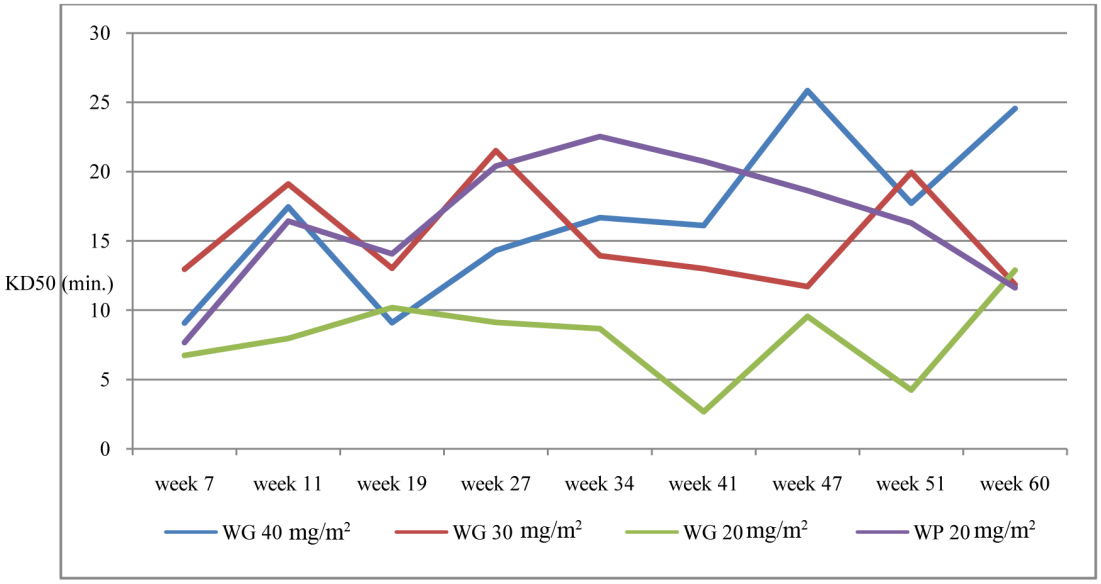


Figure 7. KD50 value (minute) of deltamethrin against *An. maculatus* sprayed rough-bamboo surfaces.

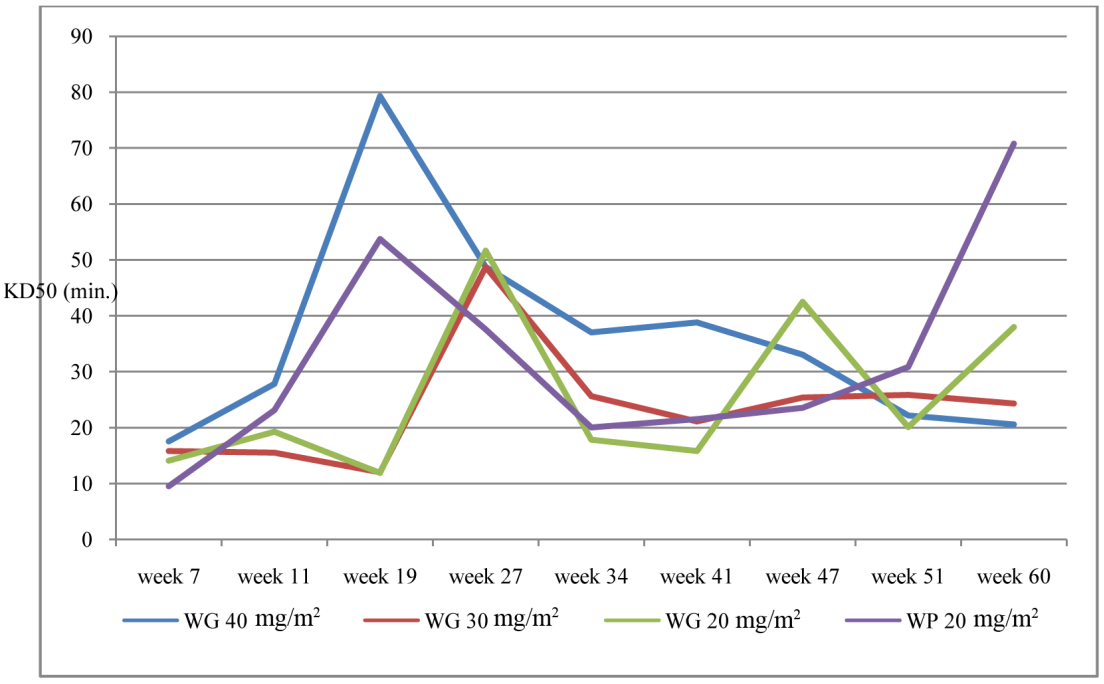


Figure 8. KD50 value (minute) of deltamethrin against *An. maculatus* sprayed on brick surfaces.

strated on all types of surfaces tested when treatments were 6 months apart. The results of this study demonstrated that deltamethrin 30 mg/m^2 WG spray deposited on all treated surfaces were effective in killing malaria vectors up to 60 weeks post-spray. However, deltamethrin at 30 mg/m^2 WG sprayed on smooth-bamboo surface, demonstrated the highest residual effect that lasted up to week 60 post spraying with mortality rate fluctuated only between 95% - 100% and KD50 value achieved within 15 min. The most interesting finding of this study is that the possibility of performing single spraying instead of two in order to have similar if not better control of mosquito in remote area. This could be achieved by employing 30 mg/m^2 WG and preferably spraying on bamboo surface.

There are several reports on the efficacy of deltamethrin on different surfaces against different species of ma-

laria vectors worldwide ([10]-[12]). Results showed that the efficacy of deltamethrin mainly depends on location, concentration of insecticide used, formulation, the surface, humidity, temperature and method of evaluation. The persistency of insecticide, as revealed by mortality, also depended on the age of spray deposit [13]. The results of the present study suggested varied durability of deltamethrin on different surfaces. Therefore, persistency of insecticides should be taken into consideration in spray round and spray cycle. The importance of a more precise definition for the duration of the residual effects is in the need to determine programming cycles in order to ensure humans remain protected until the next spraying is conducted.

5. Conclusion

In conclusion, our study shows that deltamethrin at 30 mg/m^2 WG sprayed on wooden, rough-bamboo, smooth-bamboo and brick surfaces works better than the current approach, *i.e*. a 6-monthly spraying of deltamethrin at 20 mg/m^2 WP. This formulation and dosage are highly toxic to vectors and require only one treatment per year. The killing effect is faster (15 min) and lasts longer (up to 60 weeks after spraying with 95% - 100% mortality rate) if applied on the smooth-bamboo surface and all these can be achieved with a single spraying.

Acknowledgements

The authors are grateful to the Director-General of Health, Malaysia for permission to publish this paper. We especially thanked the staff of Medical Entomology Unit of IMR and Vector Control Unit, Kuching, Sarawak, without whose diligence and hard work under difficult field conditions this research would not have been accomplished. We are alsograteful to Bayer Environmental Science for supplying the insecticides. This study was funded by National Institutes of Health (06-CAM-04-04), Ministry of Health, Malaysia.

References

[1] Vasuki, V., Rajavel, A.R., Amalraj, D.D. and Das P.K. (1995) Insecticidal Activity of Some New Synthetic Compounds against Different Mosquito Species. *Journal Communication Disease*, **27**, 146-150.

[2] Ansari, M.A., Mittal, P.K., Razdan, R.K. and Batra, C.P. (1997) Residual Efficacy of Deltamethrin 2.5 WP (K-OTHRIN) Sprayed on Different Types of Surfaces against Malaria Vector *Anopheles culicifacies*. *Southeast Asian Journal of Tropical Medicine and Public Health*, **28**, 606-609.

[3] Mulambalah, C.S., Siamba, D.N., Ngeiywa, M.M. and Vulule, J.M. (2010) Evaluation of Lamda-Cyhalothrin on Different Surfaces in a Malaria Epidemic-Prone Area in Kenya. *Research Journal of Biological Sciences*, **5**, 258-263. http://dx.doi.org/10.3923/rjbsci.2010.258.263

[4] Loong, K.P., Chiang, G.L. and Yap, H.H. (1998) Field Study of the Bionomics of *Anopheles maculatus* and Its in Malaria Transmission in Malaysia. *Southeast Asian Journal of Tropical Medicine and Public Health*, **19**, 724-728.

[5] Vector Borne Disease Control Programme (VBDCP) (2009) Sarawak. Ministry of Health Malaysia. Annual Report.

[6] Rubis, P., Chang, M.H., Nagum, A.K. and John, L.J. (1981) Parasitological and Entomological Studies on Filariasis in Seven Villages, Serian District, Sarawak, East Malaysia. *Southeast Asian Journal of Tropical Medicine and Public Health*, **12**, 30-36.

[7] World Health Organization (1998) Test Procedures for Insecticide Resistance Monitoring in Malaria Vectors, Bio-Efficacy and Persistance of Insecticides on Treated Surfaces. WHO Report 43. Bioassay Test. In: *Manual on Practical Entomology*. *Part II*. World Health Organization, Geneva.

[8] Finney, D.J. (1989) Probit Analysis. Quant: Assays Based on Quantal Response Phycological and Biochemical Methods. Cambridge University Press, Cambridge.

[9] Santos, R.L., Fayal Ada, S., Aguiar, A.E., Vieira, D.B. and Póvoa, M.M. (2007) Evaluation of the Residual Effect of Pyrethroids on *Anopheles* in Brazilian Amazon. *Revista de Saúde Pública*, **41**, 276-283. http://dx.doi.org/10.1590/S0034-89102007000200015

[10] Vatandoost, H., Abai, M.R., Abbasi, M., Shaeghi, M., Abtahi, M. and Rafie, F. (2009) Designing of a Laboratory Model for Evaluation of the Residual Effects of Deltamethrin (K-Othrine WP5%) on Different Surfaces against Malaria Vector, *Anopheles stephensi* (Diptera: Culicidae). *Journal of Vector Borne Diseases*, **46**, 261-267.

[11] Abtahi, S.M., Shaeghi, M., Abayie, M.R., Akbarzadeh, K., Vatandoost, H. and Darabi, H. (2007) Evaluation of Persistance and Residual of Deltamethrin and Cyfluthrin on Different Surfaces at Iranshar Area in Sistan and Baluchistan Province in Iran. 2004-2005. *Iranian South Medical Journal*, **9**, 123-130.

[12] Giga, D.P. and Canhao, S.R. (1991) Relative Toxicity and Persistance of Pyrethroid Deposits on Different Surfaces for

the Control of *Prostephanus truncates* and *Sitophilus zeamais*. *Journal Stored Product Research*, **27**, 153-160. http://dx.doi.org/10.1016/0022-474X(91)90039-F

[13] Govere, J., Durheim, D.N., Hunt, R.H., La Grange, J. and Coetzee, M. (2001) Evaluation of the Efficacy of Deltamethrin Using Contact Bioassay in a Malariavector Control Programme in Mpumalanga Province, South Africa. *African Entomol*, **9**, 163-166.

Scientific Research Publishing (SCIRP) is one of the largest Open Access journal publishers. It is currently publishing more than 200 open access, online, peer-reviewed journals covering a wide range of academic disciplines. SCIRP serves the worldwide academic communities and contributes to the progress and application of science with its publication.

Other selected journals from SCIRP are listed as below. Submit your manuscript to us via either submit@scirp.org or Online Submission Portal.