Research Journal of Biological Sciences 5 (3): 258-263, 2010
ISSN: 1815-8846

Evaluation of Lambda-Cyhalothrin Persistence on Different Indoor Surfaces in a Malaria Epidemic-Prone Area in Kenya

[1]C.S. Mulambalah, [1]D.N. Siamba, [2]M.M. Ngeiywa and [3]J.M. Vulule
[1]Department of Biological Sciences, Masinde Muliro University of Science and Technology, P.O. Box 190 Postcode 50100, Kakamega, Kenya
[2]Department of Biological Sciences, Moi University, P.O. Box 1125, Eldoret, Kenya
[3]Kenya Medical Research Institute, P.O. Box 1578 Postcode 40100 Kisumu, Kenya

Abstract: The residual life of pyrethroid insecticide lambdacyhalothrin (trade name: ICON) on indoor surfaces was evaluated under field conditions in villages in a highland area of Kipsamoite, North Nandi District of Kenya. About 10% lambda-cyhalthrin wettable powder was sprayed at the rate of 0.02-0.03 g m^{-2} on the indoor wall surface of randomly selected local houses. Its effect on mortality of *Anopheles gambiae s.s* as test vector was assessed from January to April 2007. Wall bioassays were conducted on different treated wall surfaces using plastic cones attached to treated surfaces at fortnightly intervals. Mortality rate in mosquitoes exposed to treated surfaces varied according to the type of wall that received the insecticide. ICON was more stable and lasted longer on mud and wood surfaces. There was significant difference between persistence of ICON on mud and other surfaces tested. For the insecticide formulation used, the duration of the residual effect was satisfactory up to the WHOPES recommended post spray period. Beyond this period, persistence declined rapidly on metal and cemented/brick plastered surfaces. The low effectiveness of the formulation on metal and cement surfaces should be considered together with the importance of residual spraying as a vector control method in the area. We concluded that the use of ICON in IRS could be a single and effective strategy to control endophiliic and antropophilic malaria vectors in malaria hypoendemic area. This is based on the findings that the local vector is susceptible to ICON and most of the houses had mud surfaces and malaria transmission is seasonal. In this regard, one round of ICON spray would be sufficient to interrupt 3-4 month seasonal malaria transmission in the study area. Apart from its toxicity to mosquitoes, ICON also agitates and repels mosquitoes that do not come in contact with it and therefore an added benefit of reducing the indoor malaria vector densities. This would drastically reduce human-vector contact and overall decline in community malaria prevalence.

Key words: Lambda-cyhalothrin, vector control, indoor insecticide spraying, residual effect/persistence, WHOPES, malaria

INTRODUCTION

Malaria is an infectious disease caused by protozoan parasites in the genus Plasmodium. The malaria parasites develop both in man as the human host and in females of some *Anopheles* mosquito species that act as vectors. Human malaria is one of the most important tropical diseases (Rojas *et al*., 1992; WHO, 1998; WHO and UNICEF, 2005). In addition to its direct health impact, the disease also imposes a huge economic burden on afflicted communities, regions and nations through high healthcare costs, missed days of researchers and school, reduced economic productivity and output and low levels of foreign investments (Sachs and Malaney, 2002).

In Kenya, nearly 7 million people reside in locations defined as highland malaria epidemic-prone areas (Hellen *et al*., 2002) and therefore require greater attention in terms of malaria control and prevention. Vulnerable populations require all proven and cost effective interventions to battle this scourge.

The discovery of effective residual insecticides in controlling malaria transmission led to intensive use of Indoor Residual Spraying (IRS) as the main measure of malaria control in the second half of the 20th century (Dixon, 1950; Roberts, 1964) and has recently been incorporated as an important component of the global malaria control strategy (WHO, 2000, 2006). The standard method of application of indoor residual

Corresponding Author: C.S. Mulambalah, Department of Biological Sciences, Masinde Muliro University of Science and Technology, P.O. Box 190 Postcode 50100, Kakamega, Kenya

insecticides was devised and perfected for applying water-based Dichloro-Diphenyl-Trichloroethane (DDT) powders to mud surfaces and thatched roofs that were common last century (Macdonald, 1957). Since then, IRS has remained the most widely used method of vector control (WHO, 1998, 2006; Najera and Zaim, 2001) using same spraying equipment and technique over the years and yet, new pesticides (USEPA, 1988; Hemingway and Ranson, 2000; Najera and Zaim, 2002) have come into use and house construction technology has changed over time.

To realize the full potential of this control tool, there is need to evaluate the effect of different surfaces on the availability of newer pyrethroid insecticides on spray-able surfaces in malaria vector control (Hemingway and Ranson, 2000). Spray-able surfaces in the tropics are presently dominated by cement, iron and wood in contrast to mud/thatch structures in the last century. Pyrethroids including lambda-cyhalothrin (trade name: ICON, one of the latest pyrethroid widely used in IRS) act as contact poisons to insect vectors that come in contact with insecticide on sprayed surfaces (A World Compedium, 1997).

We hypothesized that the insecticide/substrate interaction could limit the availability and persistence of lambda-cyhalothrin and hence affect its efficacy as an intervention strategy in malaria control. The purpose of this study was therefore to assess the persistence levels of ICON spray deposits on different surfaces.

MATERIALS AND METHODS

Study area: The study was conducted in highland area of Kipsamoite (altitude range 1900-2150 m above sea level) of North Nandi district, Kenya. The study site was selected because of accessibility, severe and more frequent malaria epidemics and outbreaks had been reported previously (Malakooti *et al.*, 1998; Shanks *et al.*, 2000). Also, the local malaria vector, *Anopheles gambiae* is known to feed and rest indoors and therefore more susceptible to IRS control strategy that was planned to take place after the baseline study.

Houses built using various materials including mud, iron, wood and cement provided an opportunity to assess the effect of each surface on the availability and persistence of insecticide over time. Indoor residual spraying was preceded by a baseline study to assess the persistence of ICON on different surfaces.

Lambdacyhalothrin 10% wettable powder available under trade name ICON was provided by World Health Organization for IRS spraying in highland areas of Kenya. Randomly selected houses were coded and classified into four categories based on the nature of wall surfaces: mud (mu), iron (me), cement (ce) and timer/wood (wo). These were further grouped into 30 sprayed as the experimental houses and 15 unsprayed as the control houses.

Other factors considered for selection of houses were accessibility and permission from house owner to use house. During surface selection, alkaline and white-washed surfaces were excluded because pyretroids are inactivated by alkaline surfaces and whitewashed surfaces (Najera *et al.*, 1998).

On the selected surfaces, areas of 1 square feet were marked at different heights (at the bottom, middle and top) with marker pen before spraying. Four squares were marked for each type of sprayed/experimental surfaces and two were marked on unsprayed/control surfaces to act as controls.

The spraying technique involved the use of pressure pumps fitted with nozzles to deliver the insecticide at recommended dosage of 0.02-0.03 g m^{-2} on the surfaces. With the spray lance kept at 45 cm (18 inches) away from the wall surface, the insecticide spray was applied in vertical swaths parallel to each other, 53 cm (21 inches) apart. Spraying was done from roof to floor using downward motion with a spray discharge rate of 740-860 mL^{-1}.

The bioassays were carried out within marked squares to assess the persistence of the residual action on various sprayed surfaces. The inhabitants were advised not to alter the marked areas by re-plastering, white washing or painting.

The persistence of the ICON on different walls was carried out in the field using standard WHO kits and associated procedures (WHO, 1981). The bioassays started on day 1 (a day after the wall spraying) and subsequently at fortnightly intervals. A total of 10 bioassays were carried out during the study. For these bioassays, laboratory maintained 3 days old strain of female *Anopheles gambiae s.s* population was used as described by Mulambalah (2009). The mosquitoes were confined to the wall surfaces in plastic cone as in Fig. 1.

At the end of 30 min of exposure to the sprayed and unsprayed surfaces, the experimental and control mosquitoes were carefully removed and placed in plastic containers covered with nylon net fastened with rubber band. The mosquitoes were provided with 10% sugar solution soaked in cotton wool placed on the nylon net and transported to the insectary at Kenya Medical Research Institute, Kisumu, Kenya. The mosquitoes were maintained in insectary at temperature of 27±2°C and 60-70% relative humidity during 24 h holding period after exposure. Thereafter, the percentage knockdown

Fig. 1: Plastic cone containing mosquitoes attached to cement insecticide treated surface

mortalities were computed from the total alive and dead mosquitoes for each type of surface. Knockdown mortality was calculated from the percentage of mosquitoes lying on their backs or sides rather than resting on their legs and was done by visual examination. Where control mortality was between 5-20%, data was corrected by applying the Abbott's formula (Abbott, 1925). When mortality in controls exceeded 20%, test results were rejected or repeated. The WHO criterion for persistence level of at least 70% mortality at week 8 after spraying was used as a standard reference (Najera and Zaim, 2001). The results were used to express the overall persistence of ICON on various wall surfaces.

Data analysis: There were significant differences in the number of dead and live mosquitoes in each bioassay (ANOVA) ($p<0.001$). The percentage mortalities were computed from total number alive and dead mosquitoes in the replicates exposed to each type of surface for each bioassay. Corrected percentage mortality was calculated using Abbott's formula when mortality in the control was between 5-20%.

The persistence of ICON on wall surfaces was derived from the percentage mortality in mosquitoes exposed to different treated surfaces. The persistence difference between and among wall surfaces was analyzed to arrive at the results presented.

RESULTS AND DISCUSSION

WHOPES recommends that an indoor insecticide be classified as persistent if it kills at least 70% of exposed mosquitoes 56 days (8 weeks) after spraying. Based on this, ICON was persistent and effective on all the four surfaces for >2 months (70 days). Thereafter, their was a rapid decline of ICON persistence on metal (me) surfaces while a gradual decline in persistence on the other 3 wall types was recorded as indicated by the mortality in experimental mosquitoes. In subsequent bioassays (after 70 days), mosquito mortality varied depending on the nature of the sprayed surface. At week 12 (84 days) the mortality was 80-97% in those mosquitoes exposed to cement (ce), mud (mu) and wooden (wo) treated surfaces. Mosquitoes exposed to sprayed metal surfaces at the same time had 67% mortality.

At the 14th week (98 days), the mortality ranged between 72-92% in mosquitoes exposed to cement, mud and wooden sprayed surfaces whereas those exposed to metal sprayed surfaces had 63% mortality.

At week 16 (112 days), mortality ranged 63-83% in mosquitoes exposed to cement, mud and wooden sprayed surfaces whereas those exposed to sprayed metal surfaces had a decreased mortality of 55%.

The effect of ICON on the sprayed walls was observed up-to 18 weeks (126 days or 4 months). At this time, the highest mortality at 78% was recorded in mosquitoes exposed to sprayed mud surface. At the same time the lowest mortality ranging from 48-58% was recorded in mosquitoes exposed to metal, wooden and cement sprayed surfaces.

This implied that ICON was more stable and lasted longer on mud surfaces than the other three surfaces. The overall results are indicated in Fig. 2. It was evident that ICON was persistent on all surfaces even beyond the WHPOPES recommended period.

However, there were significant differences thereafter in persistent levels between mud and other surfaces (t-statistic, $p<0.05$) except wood and metal surfaces (t-statistic, $p>0.05$). This implied that the type of sprayed surface was a limiting factor on the persistence of ICON on surfaces after the 58 days WHOPES recommended period.

The world Health organization recommends 12 insecticides in four chemical classes (organochlorines organophosphates, carbamates and pyrethroids) for indoor residual spraying at specific doses (Najera and Zaim, 2002). These however differ in their residual life on sprayed surfaces hence affecting their effectiveness. The effectiveness of an indoor residual insecticide depends on a complex set of factors.

These include the properties of the insecticide for instance intrinsic toxicity, mode of action and stability and its effect on the vector (Najera *et al*., 1998) were maintained. The data demonstrates that ICON was persistent and effective on different surfaces for the

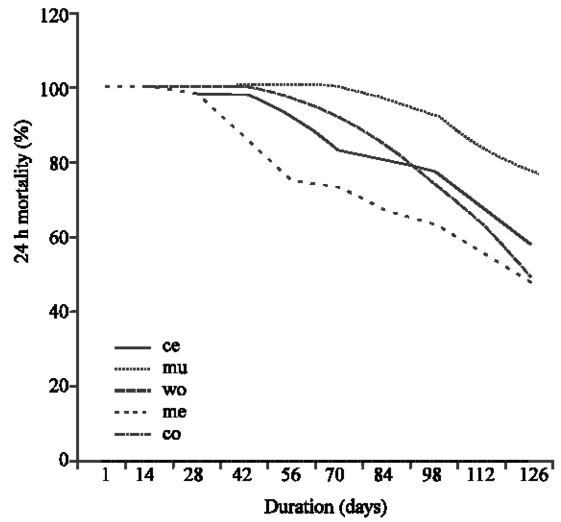

Fig. 2: Comparison of the persistence of lambda-cyhalothrin on different indoor surfaces; Ce = Cement wall surface; Mu = Mud wall surface; Wo = Wooden wall surface; Me = Metal wall surface; Co = Control

period recommended by World Health Organization Pesticide Evaluation Scheme (WHOPES). However, there were significant differences between mud and other surfaces as indicated by differences in mortality in experimental mosquitoes. We suggest that the differences could be attributed to the nature of spray-able surface. This is dependent on the absorptive and adsorptive properties of the surface. The phenomena of sorption (absorption and adsorption) of insecticides by sprayed surfaces are important that can considerably limit insecticide availability on a surface (Ferro *et al*., 1995).

Surfaces of organic origin and metals are non-sorptive and persistence of the insecticide on such surfaces depends on its volatility and therefore the physical characteristics of the formulation. ICON has a low vapor pressure and low volatility (Najera and Zaim, 2001) factors that enhance adhesiveness of the insecticide powder on a surface (if the surface is sorptive). In the absence of sorption on metal and cement surfaces therefore, prevents insecticide attachment and insecticide powder easily falls off or easily removed. Insecticides sprayed on metal and cemented surfaces as wettable powders for instance ICON are wasted or lost as a result of bouncing off and run-off (WHO, 1985).

The implication is that the surfaces retain insufficient insecticide to be effective for long enough time and therefore affect insecticide persistent levels. In addition, the heat of the sun (common in tropical areas) on metal surfaces could rapidly inactivate insecticide deposits, as well as increase the risk of the insecticide particles flaking off (De Meillon, 1936). This is not only a matter of waste. The accumulation of insecticide on the floor may be toxic to infants while the walls may not have retained enough insecticide to be effective.

These are possible explanations for the rapid decline of ICON efficacy on cement and metal surfaces. These factors should be taken into consideration in an area where the use of iron roofs and surfaces is on the increase as is often the case in many rural areas. The uneven corrugated iron sheets could also hinder or prevent spray-men adopting the pump nozzle-wall distance required leading to doubtful insecticide spray consistency (Najera and Zaim, 2001).

Insecticide applied on mud surfaces is absorbed into the body of mud, reducing its availability on the surface. However, this absorption occurs gradually at a speed related to the particle size of the insecticide, its rate of diffusion in the mud and the volatility of the insecticide. While DDT, an organochlorine is less persistent on porous surfaces such as mud, wood (Gladwell, 2001; Thurow, 2001), the studies found significant differences in mosquito mortalities in as per treated surfaces exposed to. Similar findings have been reported by Ladonni *et al*. (1992) using pirimiphos methyl on different surfaces.

For certain insecticides like bendiocarb, a carbamate, the nature of sprayed surface do not affect their residual life (Maharaj *et al*., 2004). The longer persistence of ICON on porous surfaces (mud and wood) is related to its non-volatility, low water solubility (WHO, 1990) and smaller, fine particles (Thurow, 2001; Mabaso *et al*., 2004) that enable it to stabilize adhere strongly on these surfaces. In contrast, dissipation of DDT and Hexachloro-cyclo-hexane (HCH) (organochlorines) on mud surfaces and soil is largely attributed to volatilization (Thomas *et al*., 2006).

Overall, efficacy of ICON was superior on mud and wood surfaces than metal and cemented surfaces 4 months post-spraying. The implication is that in areas where wall surfaces are mainly made of metal and cement and malaria transmission season lasts beyond 4 months, one round of IRS using IICON would not be effective. The study suggests that in such situation, two rounds of ICON spraying would be required for effective malaria control and prevention.

CONCLUSION

We conclude that indoor residual spraying with ICON could be effective because there was high percentage of spray-able surfaces within each dwelling and the targeted vector mosquito *Anopheles gambiae* was susceptible to ICON insecticide, the candidate insecticide to be used in

IRS in the study area. These are some of the pre-requisites for successful use of IRS intervention in malaria control (WHO, 2006). However, as rural areas in tropical Africa become more prosperous, there will be a shift towards western style cemented, plastered and painted housing, leaving fewer homes suitable for IRS/ICON spraying. This would necessitate the use of alternative insecticides and or malaria intervention measures.

ACKNOWLEDGEMENTS

We acknowledge technical and field assistance from Division of Vector-Born Diseases (DVBD) of the Ministry of Health, Kapsabet, Kenya and Kenya Medical Research Institute (KEMRI), Kisumu, Kenya.

REFERENCES

A World Compedium, 1997. The Pesticide Manual. 11th Edn., British Crop Protection Council, Farnham, Surrey, UK., pp: 300-302.

Abbott, W.S., 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol., 18: 265-267.

De Meillon, B., 1936. Control of malaria in South Africa by measures against adult mosquito habitations. Q. Bull. Health Org. League Nations, 5: 134-137.

Dixon, D.S., 1950. Paludrin (*Proguanil*) as a malaria prophylactic amongst African labour in Kenya. East Afr. Med. J., 27: 127-130.

Ferro, E.A., A.R. de Arias, M.E. Ferreira, L.C. Simancas, L.S. Rios and J.M. Rosner, 1995. Residual effect of lambdacyhalothrin on *Tritoma infestans*. Mem. Inst. Oswaldo Cruz, 90: 415-419.

Gladwell, M., 2001. The mosquito killer. Ann. Public Health, 2: 42-51.

Hellen, L.G., K.C. Sarah, P. Timothy, P. Robinson, A.O. Sam and W.S. Robert, 2002. Malaria prevention in highland Kenya: Indoor residual house spraying vs insecticide-treated bed nest. Tropical Medicine Int. Health, 7: 298-303.

Hemingway, J. and H. Ranson, 2000. Insecticide resistance in insect vectors of human disease. Ann. Rev. Entomol., 45: 371-391.

Ladonni, H., M. Motabar and M. Iranpour, 1992. Residual and air-borne effects of pirimiphos methyl on different surfaces in south of Iran. Iranian J. Public Health, 21: 74-85.

Mabaso, M.L., B. Sharp and C. Lengeler, 2004. Historical review of malaria control in Southern Africa with emphasis on the use of indoor residual house spraying. Trop. Med. Int. Health, 9: 846-856.

Macdonald, G., 1957. The Epidemiology and Control of Malaria. Oxford Univ. Press, London.

Maharaj, R., S. Casiminio, S.D. Mthembu and B.L. Sharp, 2004. The residual life of bendiocarb: A field based evaluation from Mozambique. J. Med. Entomol., 41: 130-132.

Malakooti, M.A., K. Biomondo and G.D. Shanks, 1998. Re-emergence of epidemic malaria in the highlands of western Kenya. Emergeing Infect. Dis., 4: 671-676.

Mulambalah, C.S., 2009. Malaria vector studies with regard to disease transmission and control in a highland area of Kenya. Ph.D. Thesis, Moi Univsersity, Kenya

Najera, J.A and M. Zaim, 2001. Malaria Vector control: Insecticides for indoor residual spraying. WHO/CDS/WHOPES/2001.3., http://209.61.208.233/LinkFiles/Dengue_Bulletin_Volume_25_Dengue-Bulletin_Vol25.pdf#page=134

Najera, J.A. and M. Zaim, 2002. Malaria vector control: Decision making criteria and procedures for judicious use of insecticides. WHO/CDS/WHOPES/2002.5, WHO, Geneva, www.who.int/ctd/whopes/docs/judiciousUseRev.pdf

Najera, J.A., R.L. Kouzntsov and C. Delacollete, 1998. Malaria Epidemics Detection and Control forecasting and Prevention. WHO Document WHO/MAL/98.1084, http://www.rbm.who.int/docs/ najera_epidemics/naj11.htm

Roberts, J.M.D., 1964. The control of epidemic malaria in the highlands of western Kenya. Part III. After the campaign. J. Trop. Med. Hyg., 67: 230-237.

Rojas, W., F. Penaranda and M. Echavarria, 1992. Strategies for malaria control in Columbia. Parasitol. Today, 4: 141-144.

Sachs, J. and P. Malaney, 2002. The economic and social burden of malaria. Nature, 415: 680-685.

Shanks, G.D., K.S. Biomondo, S.L. Hay and R.W. Snow, 2000. Changing patterns of clinical malaria since 1965 among tea estate population located in the Kenyan highlands. Trans. R. Soc. Trop. Med. Hyg., 94: 253-255.

Thomas, S., C. Hari, M.K. Agarwal and K. Pillai, 2006. Persistence and binding of DDT and gamma-HCH in a sandy loam soil under field conditions in Delhi, India. Pestic. Sci., 22: 1-15.

Thurow, R., 2001. In malaria war, South Africa turns to pesticide long banned in the west. Wall Street Journal, July 26, 2001. http://www.mindfully.org/Health/Malaria-New-Strain.htm.

USEPA, 1988. Office of pesticides and toxic substances. Fact Sheet No. 171: Karate (PP321). US. Environmental Protection Agency, Washington, DC., USA.

WHO and UNICEF, 2005. World Malaria report 2005. World Health Organization and UNICEF, Geneva. http://whqlibdoc.who.int/publications/2005/9241593199_eng.pdf.

WHO, 1981. Instructions for the bioassay of insecticidal deposits on wall surfaces. Document: WHO/VBC/81.5, Word Health Organization, Geneva, Switzerland.

WHO, 1985. Safe use of pesticides. 9th report of the World Expert Committee on vector biology and control. WHO Technol. Rep. Ser., 720: 1-60.

WHO, 1990. Cyhalothrin, environmental health criteria No. 99. Word Health Organization, Geneva, Switzerland.

WHO, 1998. Expert committee report on malaria, Twentieth report. Word Health Organization, Geneva, http://malaria.who.int/docs/ecr20_toc.htm

WHO, 2000. WHO expert committee on malaria, Twentieth report. Word Health Organization, Technical Report Series No. 892, Geneva. http://www.rollbackmalaria.org/docs/ecr20.pdf.

WHO, 2006. Indoor Residual Spraying. Use of indoor residual spraying for scaling up global malaria control and elimination. Document: WHO/HTM/MAL/2006.1112, http://whqlibdoc.who.int/hq/2006/WHO_HTM_MAL_2006.1112_eng.pdf.