

Residual insecticidal activity of long-lasting deltamethrin-treated curtains after 1 year of household use for dengue control

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Summary

OBJECTIVE To evaluate the residual insecticidal activity of the PermaNet[®] curtains on *Aedes aegypti* after 1 year of use in Thai households and to assess the influence of sun and dust exposure, washing practices and detergent use.

METHODS We sampled UV-protected PermaNet[®] curtains made of a long-lasting deltamethrin-[55 mg/m²] treated polyester netting, before (10 curtains) and after 8 (10 curtains) and 12 months (66 curtains) of household use in a field site in Chon Buri, Thailand. We assessed the residual insecticidal activity of the curtains by standard WHO bioassay, using a deltamethrin-susceptible insectarium *Aedes aegypti* strain.

RESULTS Mosquito mortality was 100% before distribution, 100% at 8 months and 98.2% (95% CI 97.9–98.5) at 12 months of use. Sunlight, hand-washing and detergent use had no effect on the residual insecticidal activity after 12 months. However, the mosquito survival rate increased by a factor of 6.4 (95% CI 3.5–11.8) on machine-washed curtains and by a factor of 2.0 (95% CI 1.4–2.9) on curtains not covered by dust.

CONCLUSION The residual insecticidal activity of PermaNet[®] curtains remains high after 12 months use under field conditions.

keywords dengue, vector control, insecticide-treated curtain, Thailand, *Aedes aegypti*, residual insecticidal activity

Introduction

Dengue haemorrhagic fever, a potentially lethal manifestation of dengue infection, causes substantial morbidity and mortality in Asia, especially among children but recently also among older individuals (Cummings *et al.* 2009; Webster *et al.* 2009). In the absence of a vaccine (Farrar *et al.* 2007), control of the vector, mainly *Aedes aegypti*, remains the cornerstone of dengue prevention (Guzman & Kouri 2002).

Recent studies indicate that long-lasting insecticide-treated materials such as window curtains, jar covers and possibly bed nets could reduce *Aedes* infestation levels (Kroeger *et al.* 2006; Lenhart *et al.* 2008; Seng *et al.* 2008; Vanlerberghe *et al.* 2009). The short-term residual insecticidal activity of long-lasting insecticide-treated (PermaNet[®]) jar covers was tested in Cambodia (Seng *et al.* 2008): after 20 weeks of use in the field, the mean 24-h mortality of a susceptible strain of *Aedes aegypti* mosquitoes was 63.3%. Apart from the short follow-up time, the

conditions of use of curtains and of jar covers are drastically different. To our knowledge, there are no published field studies on the residual insecticidal activity of insecticide-treated curtains. Long-lasting insecticide-treated bed nets, on the other hand, have been extensively studied (Graham *et al.* 2005; Kayedi *et al.* 2008, 2009; Kilian *et al.* 2008), but it would be inappropriate to extrapolate these results to insecticide-treated curtains. In most houses, window curtains are much more exposed to sunlight and dust than bed nets, and this could have a substantial influence on their activity. Moreover, PermaNet[®] long-lasting deltamethrin-treated curtains (from Vestergaard-Fransen) are, unlike the PermaNet[®] bed nets, coated with a protectant to prevent degradation of the insecticide when exposed to UV light. This could also affect the insecticidal activity.

We therefore evaluated the residual insecticidal activity of the PermaNet[®] curtains on *Aedes aegypti* after 1 year of use in Thai households and assessed the influence of sun and dust exposure, washing practices and detergent use.

Material and methods

Study design

We collected insecticide-treated (IT) curtains from a field trial site in Laem Chabang, Chon Buri province, Thailand, where IT curtains had been distributed to 2032 households as part of an implementation study (Vanlerberghe *et al.* 2008). Average temperatures in the area are 26.4, 28.9 and 28.1 °C, and average humidity is 71, 75 and 81% in winter, summer and the rainy season respectively (<http://www.tmd.go.th/en/archive/rh.php>).

The curtains under study measured 1.5 m × 1.5 or 2 m and were made of PermaNet[®] material, produced by Vestergaard-Frandsen (Denmark). This is polyester netting coated with a long-lasting deltamethrin formulation (target concentration 55 mg/m²) and with an unknown protectant to prevent degradation of the insecticide when exposed to UV light. The manufacturer states that this material does not require re-treatment and that its insecticidal effect (functional mosquito mortality) is expected to last for up to 2 years or 6 “standard” washes (<http://www.vestergaard-frandsen.com/permanet-curtain-e-brochure.pdf>, accessed 22/05/2008). At reception, households were informed on the safety of the material, on possible minor side effects during the first days of use and on maintenance of the curtains. In particular, they were instructed to wash them gently (preferably by hand) with soap or detergent, at a maximal frequency of once every 3 months, and not to dry them in direct sunlight.

We randomly selected 10 curtains before distribution to the households in February–March 2007 (T0). 8 months (T8) afterwards, in November 2007, we visited 10 randomly selected houses and sampled per house 1 of the curtains that were still hanging up. One year (T12) after the distribution, we sampled sixty-six curtains from the field site and collected additional information on their exposure to dust and sun and on washing practices. The random sample was stratified to assure inclusion of 16 machine-washed curtains. We categorized curtains as ‘covered with dust’ or ‘not covered with dust/clean’, ‘exposed to direct sunlight’ or ‘not exposed to direct sunlight/hanging always in the shade’. This information was obtained through direct observation. Information on washing practices (never washed, washed at least once, washed with machine or by hand and use of detergent or not) was provided by a household member.

Bioassays

We assessed the residual insecticidal activity of all collected IT curtains using a standard WHO bioassay method

(WHO 2005). Ten WHO bioassay cones were evenly spread over each curtain and 10 five-day-old female *Aedes aegypti* from an insectarium raised, deltamethrin-sensitive Bora Bora strain were released in each cone. The mosquitoes were exposed to the IT curtains for 3 min and then re-collected with a sucking tube and transferred into clean cups with cotton pads soaked in sugar solution on the top. Mortality of the mosquitoes and its complement, survival, was assessed after 24 h. Mosquitoes lying totally motionless after gently shaking the cup were categorized as ‘dead’, all others as ‘survived’.

As negative controls, for each bioassay, 20 female *Aedes aegypti* divided over 2 cones were exposed to an untreated surface and subsequently transferred to cups as described above. Control mortality was generally zero and always below 5%, so no assay result had to be discarded. The bioassays were carried out at the entomology laboratory of the Department of Medical Entomology, Faculty of Tropical Medicine, Mahidol University, Bangkok, Thailand.

Statistical analysis

Data were analysed using STATA 10.0 (StataCorp, Texas, USA). We calculated the proportion of mosquitoes that had died at 24 h of the total number exposed to the 10 curtains collected at T0 and T8 and to the 66 curtains at T12. To estimate the effect of curtain exposure factors (sunlight, dust, washing, use of detergent) on the mosquito survival rate, we constructed Poisson regression models with survival as dependent and one of the exposure factors as independent variable. Survival rate ratios and 24-h mortality (and 95% CI) were obtained from these models.

Ethical considerations. The IT curtain implementation study and all nested sub-studies were approved by the ethical committee that oversees research of the Institute of Tropical Medicine, Antwerp and from the ethics committee of the Faculty of Tropical Medicine, Mahidol University, Bangkok. Written informed consent was obtained from each individual household included in the study. All collected curtains were replaced by new ones.

Results

All female *Aedes aegypti* exposed to the curtains, sampled before distribution and use, died within 24 h (Table 1). The insecticidal activity of the IT curtains remained consistently high: 100% and 98.2% of *Aedes* died within 24 h after exposure to curtains used for 8 and 12 months, respectively. At 12 months, mosquito mortality was 100%,

V. Vanlerberghe *et al.* Residual insecticidal activity of insecticide-treated curtains

Table 1 Twenty four hour mortality of *Aedes aegypti* following 3 min exposure to the UV-protected PermaNet® Curtains and the influence of curtain exposure factors on *Aedes aegypti* survival. Thailand, 2007–2008. [Correction added after online publication 28 July 2010: the values for Curtain exposure factor “Covered with dust† -Yes” and “Covered with dust† -No” have now been corrected.]

Curtain exposure factor	Number of curtains	24-h mortality (95% CI)	24-h survival rate ratio*	P-value
Time hanging				
Before use (T0)	10	100%	–	–
8 months use (T8)	10	100%	–	–
12 months use (T12)	66	98.2% (97.8–98.5)	–	–
Washing†				
Never washed	18	99.3% (98.8–99.6)	1	1
Hand-washed	32	98.8% (98.3–99.1)	1.8 (0.9–3.4)	0.081
Machine-washed	16	95.7% (94.6–96.6)	6.4 (3.5–11.8)	<0.001
Covered with dust†				
Yes	37	98.7% (98.3–99.0)	1	1
No	29	97.5% (96.8–98.0)	2.0 (1.4–2.9)	<0.001
Exposure to direct sunlight†				
No	31	98.2% (97.6–98.6)	1	1
Yes	35	98.2% (97.7–98.6)	1.0 (0.7–1.5)	0.938
Use of detergent†				
No	27	98.1% (97.5–98.6)	1	1
Yes	39	98.2% (97.7–98.6)	0.9 (0.7–1.4)	0.746

*Estimated with poisson regression models.

†Data collected at T12, *n* = 66 curtains.

between 80.0 and 99.9%, and below 80.0% for 59, 4 and 3 curtains, respectively. For curtains where mortality was less than 100%, it showed little variability over the 10 cones/curtain.

Of the 66 curtains tested at 12 months, 27.3% had never been washed, 24.2% had been machine-washed and 48.5% hand-washed. Detergent had been used for 59.1% (all machine-washed and 71.9% of hand-washed curtains). Of the curtains, 56.1% were covered with dust and roughly half of them (53.0%) had been hanging in the sun for the majority of time used.

Residual insecticidal activity was above 95% irrespective of curtain exposure factor. But on curtains not covered with dust and on machine-washed curtains, *Aedes* mosquitoes had 2.0 and 6.4 times more chance to survive. Exposure to sunlight, hand-washing and use of detergent were not significantly associated with increased mosquito survival.

Discussion

After 1 year of use under field conditions for dengue control, long-lasting deltamethrin-treated PermaNet® curtains had a residual insecticidal activity of 98.2% (95% CI 97.9%–98.5%) on a susceptible *Aedes aegypti* strain. Exposure to sunlight, hand-washing and use of detergent had no significant effect on the insecticidal activity. Machine-washing considerably reduced the activity but dust, in contrast, had some protective effect.

The deltamethrin-treated material used to make the curtains is the same as the one used in the IT jar covers evaluated by Seng *et al.* (2008), except that the covers were 150 denier netting and the curtains 75 denier. After 12 months, the residual insecticidal effectiveness of the IT curtains was much higher in our study (95% 24 h *Aedes* mortality) than that of the IT jar covers after 20 weeks of field use, when mosquito mortality had dropped to 63.3%. However, the design of the study by Seng *et al.* (2008) was somewhat different: mortality was also evaluated after 24 h, but after 10 min of exposure (against 3 min in our study) on three IT jar covers, with four replicates of 15 female *Aedes aegypti* per cover (a sample size that yields lower precision). Notwithstanding, the difference between IT curtains and jar covers could be because of frequent handling of jar covers to take water, frequent wetting (and probable leaching of insecticide) or more intensive exposure of the covers to direct sunlight and other outdoor environmental factors.

On the other hand, the negative effect of machine-washing corroborates the results of a recent laboratory study that compared the impact of standardized hand- and machine-washing of different brands of long-lasting insecticide-treated bed nets on *Anopheles* mosquito knock-down and 24-h mortality (Sreehari *et al.* 2009). The precise number of washes was not available for the curtains in our study, but in the general implementation study, the median yearly frequency of washing - by hand or machine - was two, with a maximum of five for hand and four for

V. Vanlerberghe *et al.* **Residual insecticidal activity of insecticide-treated curtains**

machine-washed curtains (V. Vanlerberghe, personal communication). This, and the absence of a detrimental effect of hand-washing on residual insecticidal activity, indicate that – over the range observed – type, and not frequency, of washing reduced insecticidal effectiveness in our study.

IT curtains covered with dust had stronger insecticidal activity. This is in line with the findings of Kayedi *et al.* (2008), who observed that dust, after controlling for frequency of washing, was not a risk factor for reduced residual insecticidal activity of IT bed nets. It is hypothesized that dust absorbs insecticide and increases its bioavailability on the surface of the material. The absence of influence of exposure to direct sunlight, however, is at odds with the observations in a previous study on bed nets (Kayedi *et al.* 2008) and is most likely because of the fact that PermaNet® curtains, unlike IT bed nets, are UV protected.

In conclusion, PermaNet® curtains exhibit good residual insecticidal activity after 1 year of use under ‘real life’ conditions. This reassuring bioassay finding prompts continued research on the effectiveness of insecticide-treated materials for *Aedes* control and dengue prevention. However, it remains to be tested whether the insecticidal effect will last for 2 years – which is probably still below the potential hanging life of the curtain; further evidence is also needed on the influence of washing practices, sunlight exposure and dust: a prolonged and stable functional period will be needed to make IT curtains a cost-effective dengue control tool.

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V. Vanlerberghe *et al.* **Residual insecticidal activity of insecticide-treated curtains**

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