SMALL-SCALE FIELD TESTING AND EVALUATION OF THE EFFICACY AND RESIDUAL ACTION OF A NEW POLYMER-ENHANCED SUSPENSION CONCENTRATE DELTAMETHRIN FORMULATION FOR MALARIA VECTOR CONTROL IN MPUMALANGA PROVINCE, SOUTH AFRICA

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Introduction

Malaria vector control is primarily based on the use of insecticides. These are applied by indoor residual spraying (IRS) or by the treatment of fabrics, especially bed nets.[1] Both methods rely heavily on the pyrethroid class of insecticides.

Malaria vector control by indoor house spraying first began in the Tzaneen area, South Africa, in the early 1930s.[2,3] The first insecticide used for this purpose was pyrethrum dissolved in kerosene which was used as an indoor spray once per week. Its proven efficacy led to IRS formulations based on the organochlorine insecticide DDT in the 1940s, followed by the organochlorine dieldrin and the organophosphate insecticides malathion and fenitrothion in the 1950s, the carbamate insecticides propoxur and bendiocarb in the 1960s and 1970s respectively, and by the pyrethroids in the 1970s and 1980s.[4]

Indoor residual spraying for malaria control involves the treatment of indoor wall surfaces and eaves of dwellings in malaria affected regions with an appropriate long-lasting, residual insecticide formulation.[5] In this way indoor resting mosquitoes, including malaria vector species, are targeted. The specific objectives of IRS are to reduce the lifespan of malaria vectors, to reduce vector density and to reduce human-vector contact.[6]

The use of IRS for malaria control globally has recently been scaled up from 5% of malaria affected countries in 2005 to 11% in 2011.[7] The increasing adoption of this technology necessitates continued product and formulation development. Testing new insecticide products or new formulations under field conditions is a major step that is needed before making recommendations for their use in prevention and control of malaria. It allows such products to be assessed under natural conditions (e.g. different substrates, temperature and humidity) as well as testing their acceptability to local communities.

The aim of this project was to assess the residual activity of a new deltamethrin SC-PE formulation compared with a deltamethrin WG formulation (250 g/kg WG) and lambda-cyhalothrin CS (100 g/l CS). The deltamethrin formulations were supplied by Bayer (Pty.) Ltd. and the lambda-cyhalothrin CS was purchased commercially. Assessments were conducted on two different local indoor surfaces (mud and cement), using pyrethroid susceptible malaria vectors.

Specific objectives were:

- To evaluate the efficacy of deltamethrin SC-PE at a dose of 25 mg ai/m^2 and compare it with deltamethrin WG at a dosage of 20 mg ai/m^2 as well with lambda-cyhalothrin CS at a dose of 25 mg ai/m^2 on mud and cement indoor surfaces using a susceptible strain of the malaria vector

Anopheles arabiensis.

- To determine the persistence over time of deltamethrin SC-PE compared with deltamethrin WG and lambda-cyhalothrin CS against *An. arabiensis*.

Methods

Study site

The study was carried out in Mpumalanga Province, South Africa. Jeppe's Reef village (25°43'9.76"S; 31° 27'43.82"E), near the Swaziland border, was identified as a suitable site for these assessments. The village is in a low malaria risk area with sporadic cases and is strip sprayed (ie houses in low lying areas adjacent to streams or other water bodies). It is a semi-urban settlement with a mix of traditional mud and western-style cement houses.

Selection of participant households

Heads of households were consulted for permission to spray their dwellings. They were informed of what the study comprised.

In order to obtain the minimum number of replicates needed for statistical analysis at the end of the trial (i.e. 3 per insecticide per substrate/surface), the indoor surfaces of 24 structures were sprayed at the dosages indicated, whilst 4 were left unsprayed as controls (2 per surface type) (table 1).

Table 1: Numbers of structures sprayed by insecticide/formulation and surface type.

Indoor surface	Spray cohort (active ingredient)	Dosage mg ai/m^2	No. of structures included in the study
Mud-plastered wall	deltamethrin SC-PE	25	4
	deltamethrin WG	20	4
	lambda-cyhalothrin CS	25	4
	control	-	2
Cement wall	deltamethrin SC-PE	25	4
	deltamethrin WG	20	4
	lambda-cyhalothrin CS	25	4
	control	-	2

Spraying and safety precautions

Spraying was carried out on 12 September 2012. 15L Hudson Xpert pumps with 8002 nozzles for porous surfaces were used. Sachets and waste water were disposed of according to WHO guidelines.[5]

Only one round of spraying was done. Three spray pumps were calibrated to obtain uniform and good quality spraying for the targeted dose, and one pump was assigned for spraying each insecticide/formulation. Spray operators were persons who routinely conduct spraying for the Mpumalanga malaria vector control programme. Protective clothing, goggles, gloves, etc. are routinely provided to each operator for their general safety. Householders were informed in advance about the spraying. The spraying technique of each operator was assessed prior to the commencement of spraying. The same spray operator was responsible for all 8 structures sprayed per insecticide/formulation.

Bioassays

A laboratory colony of *Anopheles arabiensis* housed and maintained at the National Institute for Communicable Diseases (NICD) in Johannesburg was used for the bioassays. This colony (designated KGB) was established in 1975 from wild females collected in Kanyemba, Zimbabwe. It is fully susceptible to all the approved classes of insecticides.

Standard WHO cone bioassays[8] were carried out seven days post spraying and once a month thereafter for twelve months or until <80% mortality was recorded for two consecutive months, with the exception of assays on mud surfaces treated with deltamethrin WG which were continued beyond this point because mortalities remained below but close to 80% for four consecutive months. Five cones were placed on each wall at differing heights ie one cone at head height (R1), 3 cones at waist height (R2, R3, R4) and one cone below knee height (R5). Ten unfed, 2-4 day old, female mosquitoes were exposed for 30 minutes in each cone. Knockdown was recorded immediately post-exposure, again at 60 min post-exposure and final mortality recorded 24 hours post-exposure. Wads of cotton wool soaked in a 10% sucrose solution were made available to all of the test mosquitoes from the time they were removed from the cones until the 24 hour post exposure assessment.

Data recording and analysis

Bioassay results were recorded on a standard form in the field and transferred to an Excel spreadsheet in the laboratory. Data are presented as overall 24 hr post exposure percentage mortality for each insecticide/dose/ substrate per time interval post spraying.

Results

Overall percentage mortalities for unsprayed control structures by surface at each time interval post-spraying were suitably low (<20%) throughout the test period (table 2).

Table 2: Overall percentage mortalities for unsprayed control structures by surface at each time interval post-spraying of test structures. W = week; M = month.

Surface	1W	1M	2M	3M	4M	5M	6M	7M	8M	9M	10M	11M	12M
Cement	5.6	8.2	2	0	6.5	0	2.9	1	12.4	0	9.8	0	0
Mud	2.05	3.5	2.1	11.3	0	8.5	0	0	4.5	0	0	2	1

Overall percentage mortalities vs time interval post spraying for all insecticides/formulations on both surfaces are shown in table 3 and figure 1. Based on WHOPES guidelines (<80% mortality for 2 consecutive months), bioassays on all lambda-cyhalothrin CS sprayed surfaces were discontinued 2 months post spraying. Bioassays on deltamethrin WG cement surfaces were discontinued 5 months post spraying, and bioassays on deltamethrin WG mud surfaces were discontinued 8 months post spraying. Bioassays on all sprayed surfaces were conducted at 12 months post spraying.

Table 3: Overall percentage mortalities (24 hours post exposure) induced by each insecticide/formulation by surface sprayed at each time interval post-spraying. W = week; M = month. Note that the lambda-cyhalothrin CS and deltamethrin WG formulations were re-assayed at 12 months post spraying.

Treatment/ surface	1 W	1 M	2 M	3 M	4 M	5 M	6 M	7 M	8 M	9M	10M	11 M	12 M
Lambda-cyhalothrin CS Mud	95.0	78.1	57.8										58.1
Lambda-cyhalothrin CS Cement	97.2	78.5	50.0										15.1
Deltamethrin WG Mud	98.1	99.1	84.1	75.6	76.4	73.1	80.0	63.8	31.1				49
Deltamethrin WG Cement	99.5	97.5	94.7	89.0	59.4	61.1							11.7
Deltamethrin SC-PE Mud	99.5	98.1	97.3	94.8	96.1	97.5	97.9	71.3	84.7	95.1	93.9	94.8	81.8
Deltamethrin SC-PE Cement	100.0	94.9	96.4	91.9	95.6	86.3	95.9	90.8	85.5	73.5	96.9	96.9	82.8

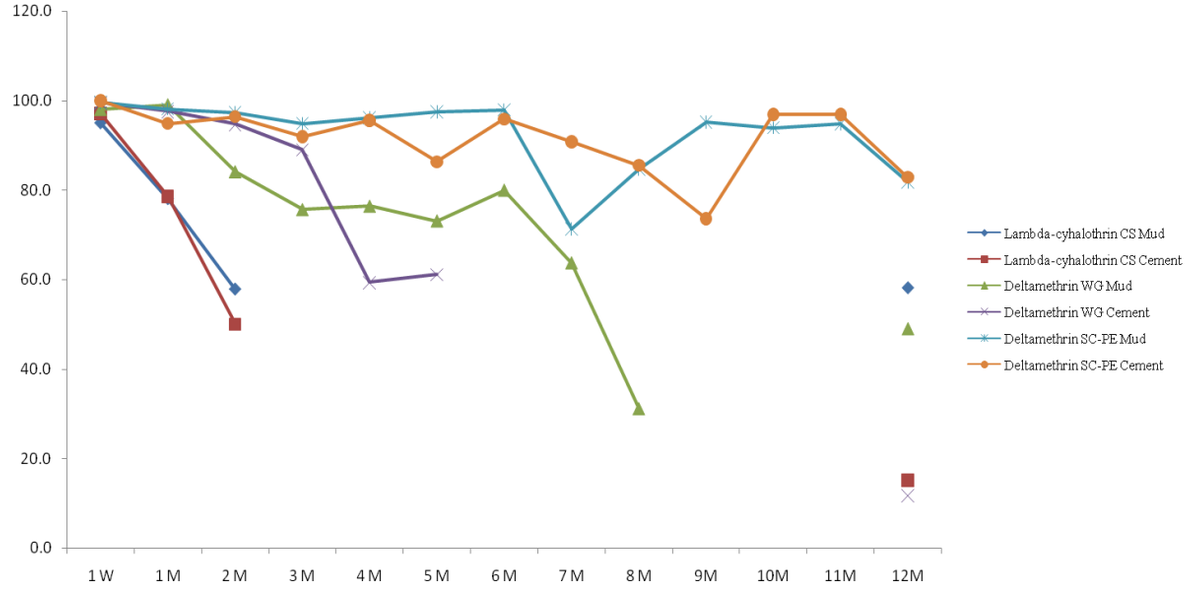

Figure 1: Overall percentage mortality induced by each insecticide/formulation by surface sprayed (mud or cement) at each time interval post spraying. W = week; M = month. Note that the lambda-cyhalothrin CS and deltamethrin WG formulations were re-assayed at 12 months post spraying.

Based on linear regression, there was no significant decrease in overall induced mortality with time post spraying for the deltamethrin SC-PE cement surfaces (F=3.01; P=0.11), nor for the deltamethrin SC-PE mud surfaces (F=3.26; P=0.1) at 12 months post-spraying. There was a significant and pronounced decrease in overall induced mortality with time post spraying for the deltamethrin WG mud surfaces (F=21.6; R^2=0.75; P=0.002) at 8 months post-spraying, and for the deltamethrin WG cement surfaces (F=20.78; R^2=0.8; P=0.01) at 5 months post-spraying.

Overall mortality induced by the deltamethrin SC-PE mud surfaces was significantly higher than that induced by the deltamethrin WG mud surfaces up to and including 8 months post spraying (ANOVA F=5.46; P=0.03). There was no significant difference in overall induced mortality between the deltamethrin SC-PE mud surfaces and the deltamethrin SC-PE cement surfaces up to and including 12 months post spraying (ANOVA F=0.15; P=0.7).

The lambda-cyhalothrin CS mud surfaces induced a similar level of mortality at 12 months post spraying to that recorded at 2 months post spraying (57.8% at 2 months vs 58.1% at 12 months). The deltamethrin WG mud surfaces induced a higher mortality at 12 months post spraying to that induced at 8 months post spraying (31.1% at 8 months vs 49% at 12 months). Conversely, mortality induced by the lambda-cyhalothrin CS cement surfaces was substantially lower at 12 months than at 2 months post spraying (50% at 2 months vs 15.1% at 12 months). Similarly, mortality induced by the deltamethrin WG cement surfaces was substantially lower at 12 months than at 5 months post spraying (61.1% at 2 months vs 11.7% at 12 months).

Discussion

Although it was not possible to assay every sprayed structure every month owing either to lock-outs (i.e. structure locked and owners absent) or destruction of mud structures, at least three structures were assayed per formulation per surface type each month as required. Furthermore, at least one unsprayed control structure per surface type was assayed on each day that assays on sprayed structures were conducted.

It should be noted that the lambda-cyhalothrin CS product had almost reached its expiry date at the time of spraying, which might account for its poor performance.

The long lasting deltamethrin SC-PE formulation significantly outperformed deltamethrin WG and lambda-cyhalothrin CS in terms of inducing mosquito mortality during the 12 month period post-spraying. Furthermore, the long lasting formulation performed equally well on mud and cement surfaces through 12 months post-spraying, without any significant decrease in efficacy over time on both surfaces during this period. However, data obtained from the lambda-cyhalothrin CS and deltamethrin WG sprayed structures showed that mud surfaces significantly outperformed the cement surfaces in terms of insecticide efficacy over time. This was especially apparent at 12 months post spraying. This is likely to prove important to future IRS operations in regions where brick and cement structures are rapidly replacing mud-walled structures.

The increasing sophistication of houses in malaria affected regions necessitates the development of malaria vector control products and technologies that are adapted to the needs of modern communities. The deltamethrin SC-PE formulation was evaluated by the WHO Pesticides Evaluation Scheme and was granted recommendation in 2013. The Report of the 16th WHOPES Working Group meeting[9] recommends the

use of deltamethrin SC-PE for indoor residual spraying against malaria vectors at a target dose of 20-25mg AI/ sqm with an expected residual efficacy of 6 months. This is valid for all surfaces, whereas lambda-cyhalothrin CS was recommended[10] with expected residual efficacy for 3-6 months, and it is not recommended for use on cement plastered surfaces.

It should be noted that new insecticide products and formulations for malaria vector control are only indicated for use in regions where the target vector population/s show full susceptibility to the active compounds. The increasing incidence of resistance to pyrethroids in malaria vector populations[11] essentially means that pyrethroid based IRS needs to be incorporated into a broader vector control scheme in accord with the principles of the global plan for insecticide resistance management (GPIRM).[12]

It is concluded that the deltamethrin (K-OthrineR Polyzone) long lasting formulation showed undiminished insecticidal efficacy up to 12 months post spraying under field conditions, was equally effective on mud and cement surfaces, and is therefore likely to prove highly effective for malaria vector control in regions where the occurrence of mud-walled structures is rapidly declining, assuming that pyrethroid resistance is not a confounding factor.

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