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A POLYMER ENHANCED FORMULATION TO PROLONG THE EFFECTIVENESS OF SURFACE SPRAYS

[1]J. KIJLSTRA, [1]G. NENTWIG, [1]F. ROSENFELDT, [1]R. SONNECK, [2]B. REID, AND [1]V. GUTSMANN

[1]Bayer CropScience AG, Research & Development, Monheim, Germany
[2]Bayer CropScience LP, Research & Development, Raleigh, USA

Abstract A new long-lasting, polymer-enhanced formulation has been developed for suspension concentrates of synthetic pyrethroids which addresses and remedies the above mentioned problems. This polymer technology, called PolyZone™ technology, prolongs the effectiveness of deltamethrin suspension concentrates on different kind of surfaces. This technology has been integrated into a new deltamethrin-based product called Deltamethrin SC-PE, which extends residuality on concrete and other materials. The World Health Organization has recently recognised this formulation as having a residual lifespan of 6 months, and it has been shown to greatly extend persistence in outdoor applications due to enhanced rain-fastness as shown in outdoor weathering trials.
Key words Residual spray, vector control, Malaria, Malaria control.

INTRODUCTION

Modern vector control relies on a multitude of tools to combat malaria transmitting mosquito vectors to limit the spread a disease that still causes several hundred thousand deaths per year, predominantly amongst young children. Although insecticide-treated nets (ITNs) and more recently long lasting insecticidal nets (LNs) are highly effective for preventing malaria, it is also recognised that by themselves LNs and ITNs are unable to deliver the reductions in malaria burden necessary to eliminate malaria in Africa and that both indoor residual spraying (IRS) and LNs should be implemented (Kleinschmidt, 2009; Hamel, 2011; Fullman, 2013).

The residual lifespan of IRS is a key element to its suitability as a control tool. Pyrethroids play an essential role in malaria vector control as roughly 50% of the WHO recommended insecticides for IRS against malaria vectors belong to this class of chemistry. Synthetic pyrethroids are commonly very stable on wood, tiles and other inert surfaces, providing good residual efficacy. On more aggressive and alkaline surfaces such as mud and concrete however, the duration of activity is often reduced (Camilleri, 1984; Demoute, 1989).

To provide an innovative deltamethrin-based IRS-solution with improved residuality also on these difficult surfaces, different formulation concepts were investigated and screened using an accelerated stress test on laboratory scale. Results of one particular concept, called polymer-enhanced formulations, in semi-field, village-scale field trials will be presented and discussed. Further studies revealed that the same technology that protects the active substance on surfaces from chemical degradation also enables the active ingredient to withstand wash-off induced by rain and irrigation. This feature is beneficial to the performance in outdoor pest control applications. Outdoor perimeter

treatment is a use pattern where the perimeter of a house is sprayed to prevent the invasion of outdoor pests into buildings. Under these weathering conditions, the main destructive factor is moisture not alkalinity (Jorgenson, 2010; Jorgenson, 2012).

MATERIALS AND METHODS

Laboratory Residual Testing

Laboratory testing of Deltamethrin SC-PE and prior development candidate formulations was done according to standardised Phase 1 testing procedures adapted from WHO guidelines on concrete and plywood materials (WHO, 2006). Blocks of substrates were sprayed using a potter tower or an automated spraying robot with correctly diluted insecticide. Surfaces were allowed to dry to completion before further handling. For bio-assays, *Anopheles gambiae* were exposed for 30 minutes before being moved into clean containers. Insecticide-induced knock-down was recorded after 1 h and 2 h, and mortality 24 h post exposure. Tests were done 1 day after spraying and subsequently every 4 weeks. 3 replicates of 10 mosquitoes were tested per treatment. In between bio assays surfaces were aged at 30°C; 80% RH without the influence of direct daylight.

Artificial Hut Residual Testing

Artificial, uninhabited simple huts were erected in Tanzania/ Lower Moshi district. These huts, measuring 3 m wide, 3 m long and with walls 2 m high were brick built structures with an iron roof and eave gaps between roof and walls. Walls were covered with different local materials such as concrete plaster (concrete/sand mix), mud, plywood and palm thatch. Walls were sprayed with a compression sprayer with diluted Deltamethrin SC-PE to achieve a surface loading of 25 mg active ingredient/m². Surface loading for the standard DDT was 2000 mg active ingredient/m². Laboratory reared mosquitoes (local susceptible *Anopheles arabinesis*) were brought into the huts every four weeks and tested in a standard cone bioassay to determine residual efficacy of the treated surfaces.

Outdoor Weathering Trials

These trials were run as variation of standard residual surface trials as described above. Instead of being aged in climate chambers, treated surfaces were moved to an outside location where surfaces were exposed to 50% shaded sun light and naturally occurring precipitation. Surfaces were then assessed in laboratory bio-efficacy trials against *Blattella germanica* as test insect on a weekly basis.

RESULTS AND DISCUSSION

Selection of Residuality Enhancing Formulations

The formulation finding process explored a new in-situ encapsulation technology by using aqueous polymer dispersions (latices) which are suitable to form water-insoluble polymer films upon spraying and drying. Since incorporation of these latices into solid formulations is not possible, we have been focusing on the development of liquid formulations. Bioefficacy screening of various polymer adjuvants on laboratory scale resulted in the identification of only one class of polymer adjuvants of interest. This polymer class is characterised by a set of unique polymer and physical-chemical properties, being responsible for the improved residuality on porous, alkaline surfaces.

We propose a mode of action where the polymer particles act like a protecting primer and only partially encapsulate the active microcrystals on the surface, ensuring bioavailability and protection against surface alkalinity. The electron micrograph shown in Figure 1 of active microcrystals with polymer on a surface seems to suggest this.

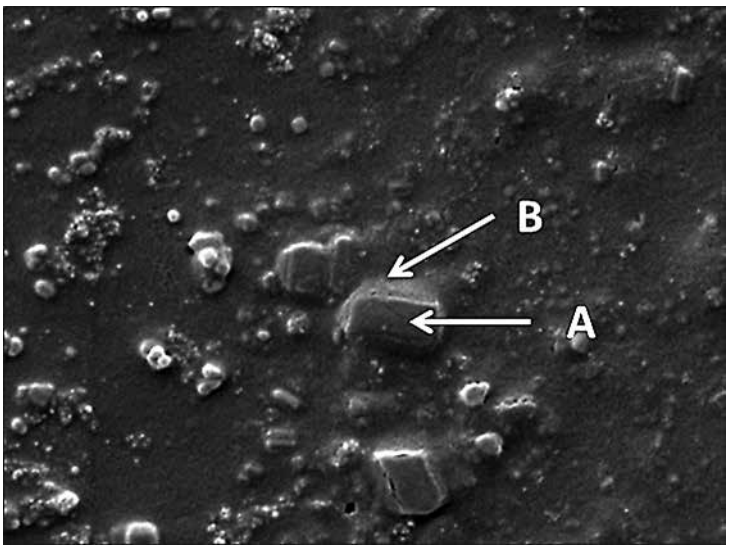

Figure 1. Transmission electron microscopy picture of partially embedded Deltamethrin crystals in a polymer film on a non-porous surface. A: Deltamethrin microcrystal ; B: polymer deposit.

Performance on Two Surfaces in the Laboratory

The formulation was tested on two surfaces against K-Othrine® WG 250 (Deltamethrin WG 250), an existing deltamethrin-based vector control product (Figure 2). On concrete, Deltamethrin WG 250 at a rate of 25 mg active ingredient/m² showed reduced performance from week 12 onward. Final mortality levels occasionally exceed 80% after 24 hours, but mortality values fluctuated greatly which was an indication of insecticide levels being at breaking point. Deltamethrin SC-PE applied at the same rate had residuality levels well above 80% for at least 52 weeks. On an inert wooden surface, Deltamethrin WG 250 and Deltamethrin SC-PE showed excellent performance (data not shown). Throughout the trial duration of 80 weeks, none of the three treatments fell below the threshold of 80% mortality after 24 hours. The surfaces were stored under stress conditions of 30°C and 80% RH between trials.

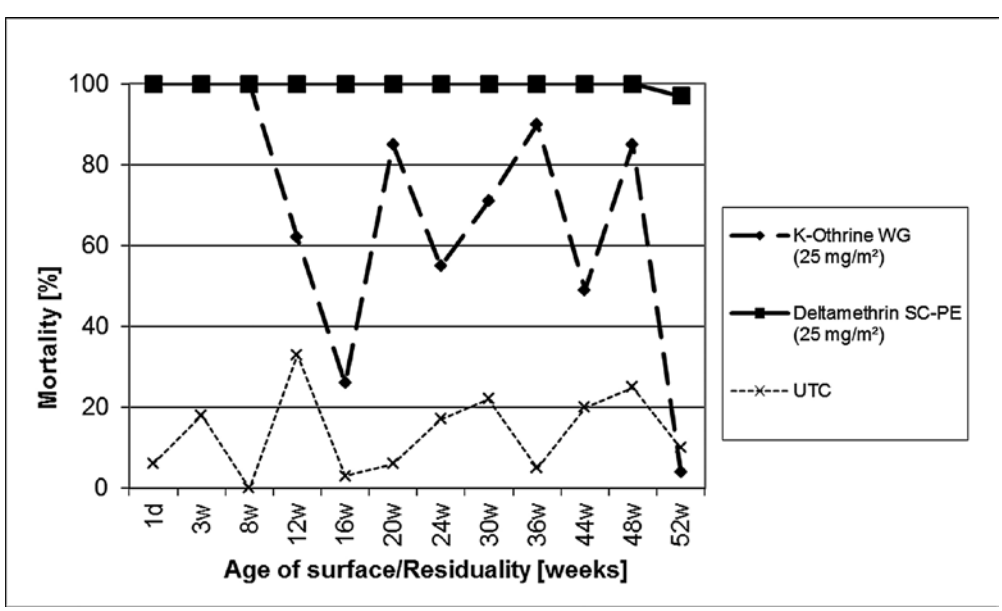

Figure 2. Final (24 h) mortality of *Anopheles gambiae* after 30 minute exposure to sprayed concrete surfaces.

Performance n Artificial Huts in Tanzania

For confirmation of the suitability of dose and residuality tests were carried out under natural condition in Africa by spraying locally-used housing materials and testing the residual effect by means of cone bioassays. In huts, mud, concrete plaster, plywood and palm thatch walls were treated and periodically bio-assayed. The treatments compared were Deltamethrin SC-PE sprayed at 25 mg DLT/m^2 and a DDT based product at 2000 mg DDT/m^2. In bioassay results depicted in Figure 3, Deltamethrin SC-PE showed better initial kill and longer residual activity than DDT on concrete by killing a greater proportion of *A. arabiensis* for a longer period. On mud and wood performance of Deltamethrin SC-PE and DDT were similar (data not shown).

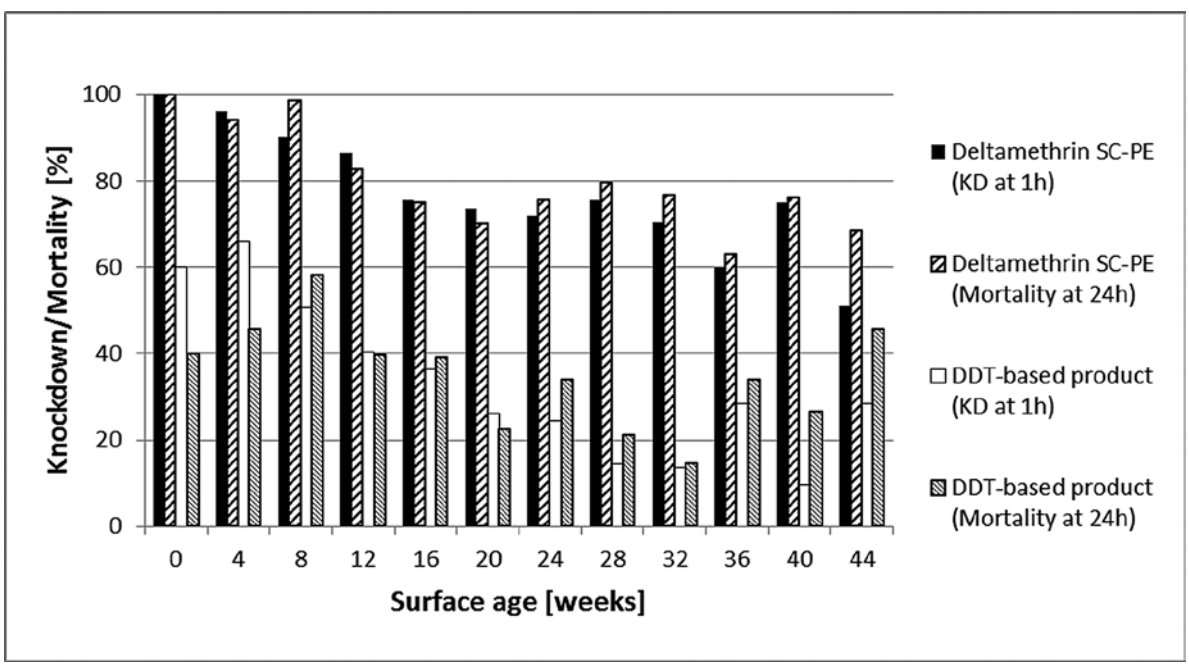

Figure 3. Knockdown and mortality of *A. arabiensis* on concrete walls aged in huts in Tanzania. Deltamethrin SC-PE used at 25 mg/m² and the DDT-based product was applied with 2000 mg/m².

WHOPES Evaluation and WHO Recommendation

Deltamethrin SC-PE was evaluated in the WHO certification process run by World Health Organization Pesticide Evaluation Scheme (WHOPES). Following this 3 phase process, a recommendation was issued and reported by the annual WHOPES working group. Using trial data of Deltamethrin SC-PE from laboratory scale, small scale field trials and village scale field trials by the WHO in Vietnam, India and Mexico and supportive data submitted by industry, the following recommendation was issued in July 2013: The use of Deltamethrin SC-PE for indoor residual spraying against malaria vectors at a target does of 20-25 mg active ingredient/m² will result in residual efficacy of 6 months (WHOPES, 2013). All other pyrethroids, including other formulations of Deltamethrin, have a recognised residual efficacy of 3 to 6 months; the fact that there was no lower limit range for Deltamethrin SC-PE indicates that it is recognised as being the longest lasting residual pyrethroid product available for malaria control.

Outdoor Weathering Trials

Evaluations were conducted to determine whether the PolyZone™ technology has an impact on outdoor, weather-induced destruction of insecticidal layers. Trials assessed the resistance of Deltamethrin SC-PC compared against various commercial insecticide formulations to exposure to UV radiation in sunlight with daily temperature fluctuations and exposure to rainfall or irrigation (Jorgenson, 2010; Jorgenson, 2012).

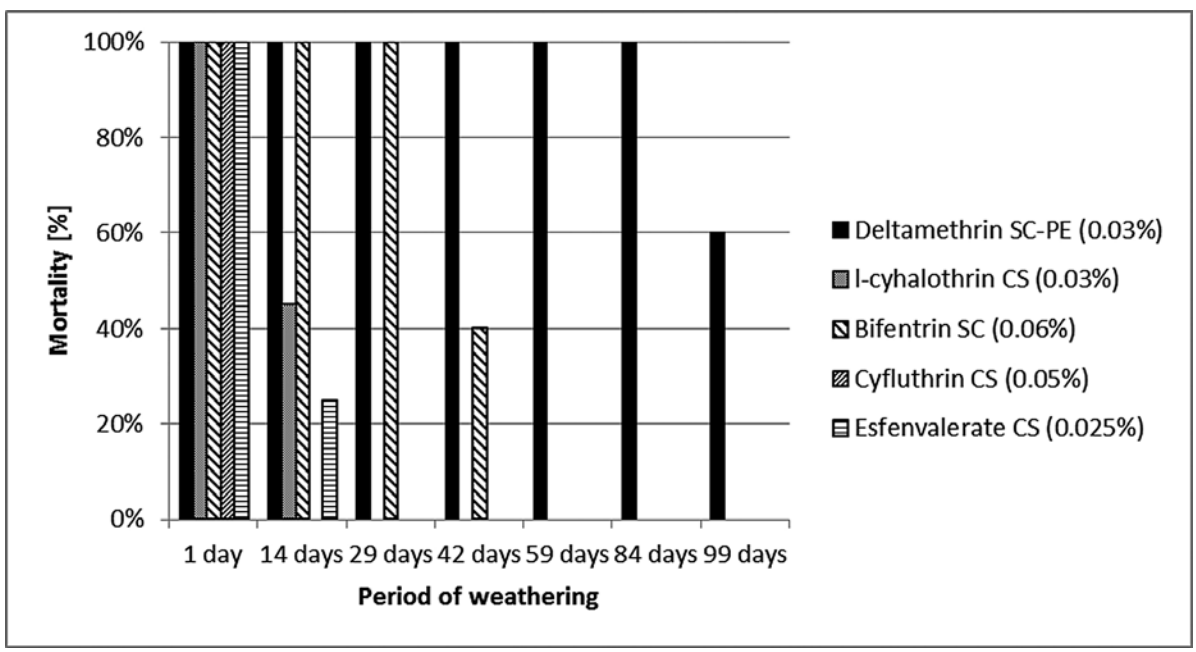

Figure 4. Mortality of *B. germanica* exposed to surfaces treated with the given insecticidal products at the indicated rate. Total rainfall in the test period was 177 liter/m².

Insecticidal formulations were sprayed onto surfaces at label rate. Treated surfaces were exposed to naturally occurring weathering conditions and periodically assayed for bio efficacy as described above. Deltamethrin SC-PE showed an extended period of full effectiveness. Figure 4 shows that Cyfluthrin CS was ineffective and l-cyhalothrin and Esfenvalerate CS were ineffective after 14 days of exposure to outdoor aging. The suspension concentrate of bifentrin caused substantial mortality for 1 month. Deltamethrin residues protected in the PolyZone™ formulation remained 100% effective through 3 months of weathering.

CONCLUSION

Data presented in this paper demonstrate that a novel polymer enhanced technology provides a longer residuality for key use pattern. Deltamethrin SC-PE extends effective insect control both in indoor applications on difficult aggressive surfaces, as well as in outdoor conditions under the influence of precipitation. Longer residuality decreases the frequency of insecticide re-application which reduces the output of chemicals into the environment and improves the operational efficiency of anti-Malaria spray teams or pest control operators.

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