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A new clothing impregnation method for personal protection against ticks and biting insects

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Abstract

The efficacy and residual activity of a factory-based, permethrin-impregnated military battle dress uniform (BDU) using a new polymer-coating technique has been evaluated by laboratory and field testing during deployment to Afghanistan and compared with two commercially available, widely used dipping methods. Residual permethrin concentrations and remaining contact toxicities on treated fabrics before laundering, after up to 100 launderings as well as after being worn-out during deployment were tested against *Aedes aegypti* (L.) and *Ixodes ricinus* (L.). The residual amount of permethrin was considerably higher with the polymer-coating technique with 280 mg/m^2 remaining after 100 launderings. Polymer-coated BDUs collected for disposal after being worn-out during military deployment showed equivalent or better residual knockdown efficacy against test arthropods when compared with the results obtained with the US Army IDA (Illinois Department of Agriculture)-Kit after 50 launderings, which represent the recommended baseline for re-impregantion or disposal of the impregnated fabric. BDUs impregnated by the polymer-coating method were found to be effective throughout the lifetime of the uniform, ensuring protection of soldiers in the field from arthropod vectors, while simultaneously decreasing logistical constraints and occupational health threats.

Keywords: Arthropods; Impregnated clothing; Repellents; Permethrin; Vectors

Introduction

Among the increasing number of arthropod-borne diseases, only few are preventable by vaccines. Although chemoprophylactic drugs are available for the prevention of malaria, drug resistance is currently on the increase and spreading geographically throughout many parts of the world. For this reason, personal protective measures against biting arthropods and arthropod-borne diseases constitute the first line of defense. A major advance in the protection of high-risk personnel (e.g. outdoor workers, travellers, and soldiers) has been the development of topical repellent formulations and residual insecticides that can be impregnated into clothing, tents, and netting (WHO, 2001a, b).

Permethrin, a synthetic pyrethroid insecticide that combines the essential qualities of repellency, hot-feet, knockdown, kill and residual activity, has widely been used for decades as an arthropod contact repellent in fabric impregnation (Young and Evans, 1998). Although permethrin is characterized by a high level of potency against a wide range of vector insects and ticks, multiple repellent and toxicological effects on arthropods, rapid reactivity, excellent photostability,

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resistance to weathering and low mammalian toxicity, its incorporation into human clothing, and peripheral protective devices must be accomplished safely, while remaining cost effective and easy to use (Faulde, 2001). Safe use and self-application of products is especially important because permethrin-treated equipment is likely to be used by thousands of inexperienced tourists, refugees, military, and disease-threatened populations in the Third World.

The purpose of this study was to analyze the contact toxicity and residual activity of new polymer-coated, factory-treated clothing. These uniforms were worn and washed under field conditions until disposal during military deployment and tested against *Ixodes* (*I.*) *ricinus* nymphs and adult *Aedes* (*A.*) *aegypti*, while compared with two widely used, commercially available dipping methods.

Materials and methods

Test arthropods

A. aegypti eggs were obtained from a continuously for more than 40 years reared colony from the German Federal Environmental Agency, Berlin. Eggs were deposited in distilled water and hatched larvae were fed with homogenized Tetramin® fish food until adult emergence. A regimen of 27 °C, 70% r.h., and a photoperiod of 12:12 (L:D) was maintained throughout the study. Adults were fed with 10% sucrose solution, and only nonblood-fed female mosquitoes, 5–8 days old, were used. *I. ricinus* nymphs were collected by the flagging method in natural habitats on the Kühkopf mountain, Koblenz, Germany, then transported in glass vials at 18 °C, 90% r.h., and used immediately in laboratory tests.

Permethrin impregnation of fabric

Factory-based permethrin-impregnated military battle dress uniforms (BDUs) were supplied by UTEXBEL S.A. (Ronse, Belgium). Fabrics were polymer-coated with permethrin (cis:trans = 25:75%) on 10,000 m rolls after the dyeing process, but before tailoring. This method yielded a theoretical permethrin concentration of 1300 mg a.i./m^2 (a.i.: active ingredient) subsequently to inprocess-heating to 130 °C, and binds solubilized permethrin into the polymer layer on the surface of the treated fabric. Uniforms impregnated by the Insect/Arthropod Repellent Fabric Treatment® (IARFTequal;US Army IDA-Kit, Coulston Products Inc., Easton, PA, USA) and the Peripel 10® (AgrEvo, Berkhamsted, Herts, United Kingdom) dipping methods were treated according to the manufacturer's instructions. When using the dipping methods, permethrin is absorbed only on the surface of the fibers. The standard military uniform fabric used for each permethrin treatment consisted of 80% cotton and 20% polyester fibers, with a specific weight of 300 g/m^2 for trouser fabric, and 210 g/m^2 for shirt fabric.

Laundering procedures

Freshly permethrin-impregnated uniforms treated by the three different methods were washed separately according to the European Norm 26,330:1993/ISO 6330:1984 at 60 °C using a commercially available light-duty detergent (Burti, Burnus GmbH, Darmstadt, Germany). Samples were taken after 0, 1, 5, 10, 20, 40, 60, 80, and 100 launderings and air-dried.

Permethrin quantification

Measurement of permethrin in washed and unwashed fabrics was accomplished using the validated method of the Bundeswehr Research Institute for Materials, Explosives, Fuels, and Lubricants. Samples were taken from different locations on the material and cut into pieces of approximately 0.5 × 0.5 cm. All pieces were combined and mixed thoroughly. Fifty milliliters of toluene (Merck, Darmstadt, Germany) were added to an aliquot (5 g) of each sample. For extraction, the samples were treated in an ultrasonic bath. Toluene extracts were dried over sodium sulfate. After the addition of hexachlorobenzene (Fluka Chemie, Deisenhofen, Germany), an internal standard analysis was performed by capillary gas chromatography/mass spectrometry in the selected ion monitoring mode using an HP 5989B mass spectrometer combined with an HP 5890 gas chromatograph, both from Agilent Technologies (Waldbronn, Germany) according to Faulde et al. (2003).

Uniform use during deployment

In spring 2003, freshly factory-impregnated BDUs were provided to the German Contingent of the Implementation Forces Afghanistan within the Kabul area. Deployment time was generally 6 months. Uniforms were worn during regular duty in the field and washed every 1–2 days by the ECOLOG company (Kabul, Afghanistan) using commercial washing machines and detergents. Worn-out or damaged BDUs collected for disposal after 70–100 launderings were analyzed for quantification of residual amounts of permethrin and remaining knockdown activity. All BDU samples were randomly collected.

Testing procedures

Plastic test tubes from the WHO insecticide susceptibility kit (WHO, 1970) were used and simultaneously the 'cone test' using laboratory glass funnels, 13 cm in diameter. Test arthropods were constantly exposed to test fabrics after 0, 1, 5, 10, 20, 40, 60, 80, and 100 laboratory launderings as well as to the BDU samples obtained during deployment to Afghanistan, and to negative controls. Adult *A. aegypti* were stored for 30 min at +10 °C prior to testing to reduce motility, collected in glass test tubes, and quickly transferred to the WHO plastic test tubes or glass funnels. *I. ricinus* nymphs were transferred using tweezers. Ten test arthropods were exposed simultaneously per run. The time of exposure necessary to obtain knockdown was measured. Knockdown (according to the definitions of the WHO and the German Federal