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Evaluation of a Cold-Water Hand-Washing Regimen in Removing Carbaryl Residues from Contaminated Fabrics

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Exposure to pesticides continues to be a problem for agricultural workers, especially those involved in mixing and applying these chemicals. The majority of human exposures to pesticides is by dermal contact (Wolfe et al. 1975; Gold et al. 1982; Spencer et al. 1995; Simcox et al. 1999; Doran et al. 2000) and often occurs when agrochemical workers wear contaminated clothing. For example, researchers have found that herbicide applicators wearing contaminated clothing have greater levels of exposure than other workers (Lavy et al. 1983). Also, because contaminated clothing may act as a reservoir for pesticide residues, refurbishment of these clothes is important in limiting worker exposure to pesticides. As a result, appropriate methods to refurbish contaminated clothing need to be identified to reduce the risk of pesticide exposure. Most studies on pesticide residue removal from clothing have evaluated different types of fabric, detergent, pesticide formulation, wash-water temperature, and laundry procedures using washing machines (Kim et al. 1986; Nelson et al. 1992; Laughlin 1993; Perkins et al. 1996). However, information is lacking on the effectiveness of cold-water, hand-washing regimens that are common in many developing countries where washing machines and hot water are often not available.

In South Africa, for example, the vast majority of small-scale agricultural workers do not have access to washing machines or hot water. Therefore, these workers tend to follow a particular cold-water, hand-washing regimen. Clothing is soaked, scrubbed by hand using cold-water-formulated detergent or hand soap, and air-dried; bleach may be added if clothing is particularly soiled. The objective of this study was to identify the most effective cold-water, hand-washing regimen for removing carbaryl insecticide from contaminated fabric typically worn by agricultural workers in rural South Africa using South African laundering products.

MATERIALS AND METHODS

One heavy-weight fabric and two light-weight fabrics were used in this study. The two light-weight fabrics were 100% cotton and 50/50 cotton/polyester and had weights of 191 g/m^2 and 208 g/m^2, respectively. The heavy-weight fabric was 100% cotton denim with a weight of 450 g/m^2. The two light-weight fabrics

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are typical "T-shirt material" and the denim is a typical trouser fabric commonly worn by rural South African agricultural workers. The fabrics were cut into 5 x 13 cm swatches and prewashed. A liquid formulation of carbaryl (Sevin®), a carbamate insecticide, was dissolved in acetone and 1 mL of solution (3 mg carbaryl) was added evenly to each individual fabric swatch (4 replicates per treatment). Treated swatches were air-dried in an incubator maintained at 30°C. Half of the treated fabric swatches were washed 4 hr after treatment and half were washed after 96 hr.

Laundering consisted of the following treatments:

(1) Detergent (OMO, Lever Brothers Ltd., Durban, South Africa) – Treated fabric swatches were soaked for 10 min in 0.3 g detergent dissolved in 150 mL water. After soaking, swatches were hand-scrubbed for 20 sec and rinsed for 10 sec in distilled water. Fabric swatches were allowed to air-dry for 24 hr before analysis using gas chromatography.
(2) Detergent plus bleach (Clorox, The Clorox Company, Oakland, CA; 6% sodium hypochlorite) – Treated fabric was soaked for 10 min in 0.3 g detergent and 0.5 mL bleach in 150 mL water. After soaking, swatches were washed and dried as described above (0.02% sodium hypochlorite).
(3) Bleach – Treated fabric was soaked for 10 min in 0.5 mL bleach in 150 mL water. After soaking, swatches were washed and dried as described above.
(4) Soap (Sunlight, Lever Brothers Ltd., Durban, South Africa) – The treated fabric swatch was placed so that the entire fabric swatch was in contact with the soap bar. The swatches were then hand-scrubbed and dried as described above.
(5) Water – Treated fabric was soaked for 10 min in 150 mL of water. After soaking, swatches were washed and dried as described above.

After washing, fabric swatches were air-dried overnight and then extracted three times with 60 mL acetone. The resulting extract was concentrated under nitrogen flow, and analysis of the extracts was performed by gas chromatography with thermionic specific detection (GC-TSD, Varian, Walnut Creek, CA).

Analysis of variance (ANOVA) was used to determine any treatment effects on removal of carbaryl from fabrics 4 and 96 hr after application. When the F-value for the overall test was significant ($p < 0.05$), Fisher's least significant difference test was used to determine significance among treatments.

RESULTS AND DISCUSSION

The amount of carbaryl removed by a cold-water, hand-washing regimen commonly followed by rural South African agricultural workers ranged from 37–96%. Although there was no significant difference in the amount of carbaryl removed from any fabric type laundered 4 or 96 hr after contamination occurred, several factors did significantly affect removal of carbaryl from clothing, including laundering treatment. Detergent and a detergent-bleach mixture were

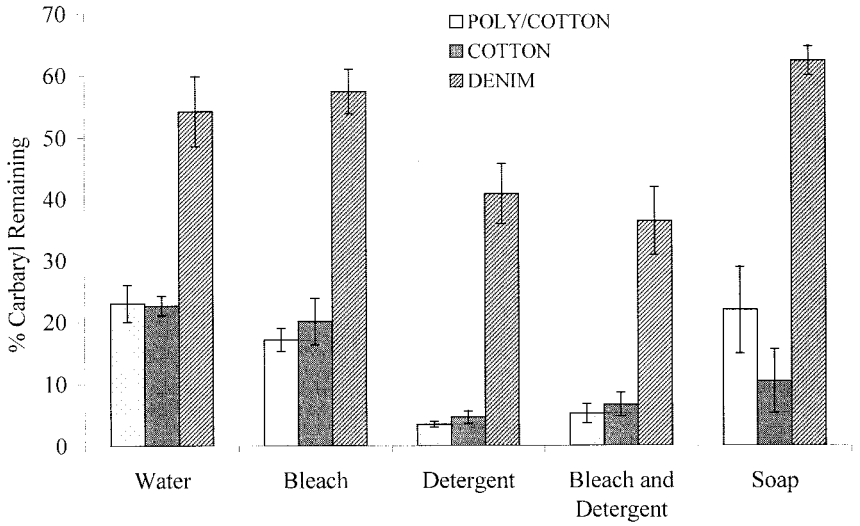

Figure 1. The percentage of carbaryl removed by laundering 4 hr after application of carbaryl.

most effective in removing carbaryl from each fabric type compared with other treatments ($p < 0.01$; Figures 1, 2). However, the detergent-bleach mixture did not remove significantly more carbaryl than detergent-only, and bleach, soap, and water-only treatments were least effective in removing carbaryl from fabric. Similar results were found by Lillie et al. (1981) who showed that a detergent-bleach mixture, using a washing machine, did not remove significantly more diazinon from 100% cotton fabric than detergent-only. Carbaryl, a carbamate, and diazinon, an organophosphate, are both quite sensitive to hydrolysis in alkaline aqueous solutions, but stabilized in acid solutions. Therefore, it is not surprising that these two insecticides are not degraded appreciably in an aqueous bleach (acidic) solution.

Carbaryl residue removed by laundering was also dependent on fabric type and weight. We found that significantly higher ($p < 0.01$) concentrations of carbaryl remained in denim (heavy fabric) compared with 100% cotton and 50/50 cotton/polyester (lighter-weight fabrics) after laundering (Figures 1, 2). The amount of carbaryl removed from cotton and cotton/polyester fabrics ranged from 69–96% and 57–95%, respectively; but only 37–63% of carbaryl was removed from the denim fabric. Previous work by Laughlin et al. (1991) found that 356 g/m^2 fabric retained significantly less cyfluthrin residue than 475 g/m^2 fabric after laundering, and Kim et al. (1982) found that high fonofos (41–80%) residues remained on denim fabric after laundering. Also, Easley et al. (1982) found that a minimum of three launderings (machine washing) was necessary to reach harmless levels of methyl parathion residues in denim.

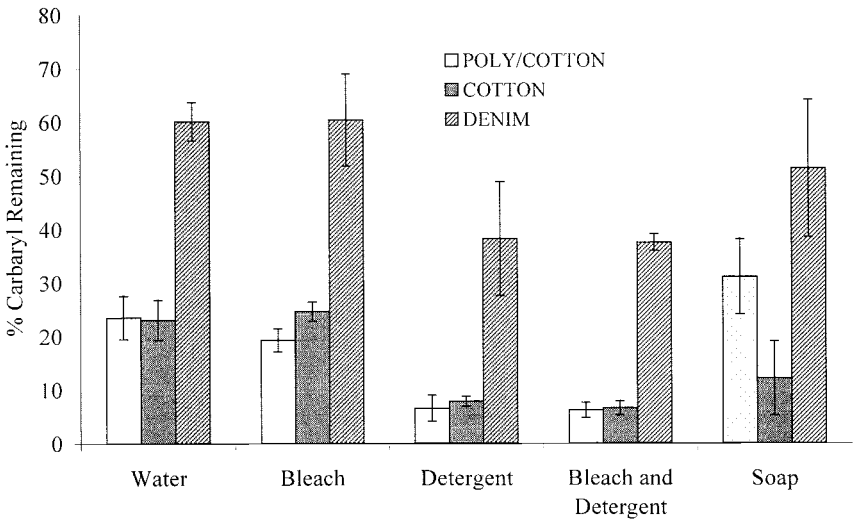

Figure 2. The percentage of carbaryl removed by laundering 96 hr after application of carbaryl.

The increased retention of pesticide residues by different fabric types after laundering may be caused by increased penetration and binding of the pesticide. For example, Obendorf and Solbrig (1986) found that malathion and methyl parathion residues were in the lumen of cotton fibers, but only on the surface of cotton/polyester fibers before laundering. In addition, they found that laundering was effective in removing the pesticides from cotton/polyester, but had little effect removing residues from cotton lumen.

Based on the results of this study, hand-washing using a cold-water-formulated detergent (OMO) is effective at removing carbaryl from light-weight fabrics (100% cotton and 50/50 cotton/polyester), but not in removing carbaryl from a heavy-weight 100% cotton denim fabric. In addition, even though lighter-weight fabrics show lower pesticide residue retention after laundering, it is premature to recommend them for use as protective clothing because pesticides may penetrate more rapidly through lighter-weight fabric and be absorbed by the skin. Therefore, additional research is needed to find a successful cold-water, hand-washing regimen that can be used to remove residues from denim fabric in parts of the world that do not have access to washing machines or hot water.

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