Bull. Environ. Contam. Toxicol. (1996) 56:935-941

Bulletin of Environmental Contamination and Toxicology

Effect of Abrasion on Protective Properties of Polyester and Cotton/Polyester Blend Fabrics

A. Shaw,[1] Y. J. Lin,[1] E. Pfei1[2]

[1]Department of Human Ecology, University of Maryland Eastern Shore, Princess Anne, Maryland 21853, USA
[2]Agricultural Research Services, U.S. Department of Agriculture, Beltsville, Maryland 20705, USA

Received: 5 October 1995/Accepted: 14 December 1995

Simulated wear studies are important in the development of pesticide protective clothing, because the physical and chemical properties are altered during wear (Laughlin and Gold, 1987). Changes due to abrasion affect the mechanism of sorption and penetration of pesticides. Research conducted at the University of Maryland Eastern Shore show that application of Zonyl® finish (fluoroalkyl methacrylate polymer) drastically reduced the sorption and penetration of pesticide through cotton, polyester, and cotton polyester blend fabrics (Shaw, 1992). As surface properties change due to abrasion, the level of protection provided by "worn" fabrics against pesticides may change. This study was conducted to determine the effect of surface abrasion on the sorption and penetration of pesticide through fabrics.

MATERIALS AND METHODS

A 2 x 7 x 2 factorial design was used for the study. The three factors were fabric, level of abrasion, and fabric finish. Two sets (with three replications) of fabric specimens were tested for each combination. Gas chromatograph (GC) was used to quantify the amount of pesticide remaining on one set of fabric specimen. Backscattered electron imaging (BEI) on scanning electron microscopy (SEM) was used to study the distribution of osmium tagged pesticide on the second set of fabric specimens.

Zonyl® (fluoroalkyl methacrylate polymer) was applied commercially to cotton/polyester and polyester test fabrics. Fabric characteristics are given in Table 1. Emulsifiable concentrate (95% a.i.) of metolachlor was used for the study. The percent active ingredient was verified by GC.

ASTM test method D3884-92 was used to abrade the 15x15 cm test specimens for 0, 10, 25, 50, 100, 250, or 500 cycles respectively. A template (Fig. 1) was used to cut two 5 cm x 5 cm fabric specimens (A and B) for pesticide contamination. Specimen A from each abraded sample was used for GC analysis,

Correspondence to: A. Shaw

Table 1. Physical characteristics of fabrics used for the study.

Fiber Content	Weight (g/m^2)	Weave	Yarn Count/inch
Cotton/polyester	190.9	Plain	119 x 65
Polyester (100 %)	212.2	Plain	43 x 41

and specimen B was used for SEM analysis. For pesticide contamination, three layer composites were prepared; abraded test fabric (top layer) was used to measure sorption, and collector layers (knit fabric and foil) were used to measure penetration. A constant-volume micropipette was used to apply 0.1 mL of pesticide to the center of the abraded area. Excess pesticide was removed from the surface after 10 minutes (Shaw and Hill, 1991). The top layer was then separated from collector layers, and all layers were air-dried overnight at room temperature.

For GC analysis, layers to measure sorption and penetration were extracted and analyzed separately. Acetone (50 mL) was used to extract the metolachlor using an orbital shaker at 200 rpm for 45 min. The procedure was repeated twice. Hewlett Packard 5890 GC equipped with nitrogen/phosphorus detector (NPD) and 30 m x 0.32 mm id fused silica capillary column was used for analysis. The oven temperature and carrier gas were 240 °C (isothermal) and helium, respectively. The concentrations of pesticide were converted to percent applied and expressed as means and standard deviations. GC data were also statistically analyzed using analysis of variance (ANOVA) and least significant differences (LSD).

For SEM analysis, fabric strips from the control and contaminated specimens (top layer) were labeled with osmium tetroxide (OsO_4) vapors (Shaw, 1991). Labeled specimens from the front and back of the specimens were mounted on carbon stubs and then carbon coated in a Fullum carbon fiber coater. Electroscan environmental SEM (ESEM model E3) was used to analyze specimens at 150X and 500X magnifications using 30 kV probe current. Backscattered electron imaging was used to study the distribution pattern of the pesticide on the surface of the fabrics, and X-ray analysis was used to identify the osmium peaks.

RESULTS AND DISCUSSION

Gas chromatograph analysis revealed that the amount of pesticide sorbed by unfinished fabrics was considerably higher than the amount sorbed by fabrics with Zonyl finish (Fig. 2-5). As seen in Fig. 2, pesticide sorbed by unfinished cotton/polyester fabrics were more than the amounts that penetrated to the collecting layers. Unfinished cotton/polyester fabrics abraded to 50, 100 and 250 cycles retained more pesticides than unabraded specimens. This was due to the protruding and entangled fibers on the abraded surface. After the fabrics were abraded for 500 cycles, the amount of pesticides sorbed was lower, as the number of entangled fibers on the surface decreased due to fiber breakage. Figure 6

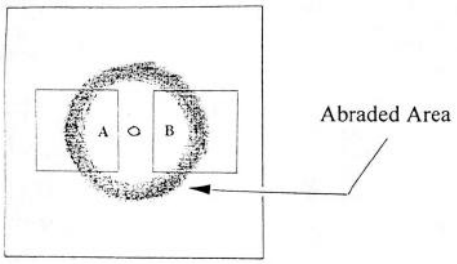

Figure 1. Schematic diagram of the template used for the study

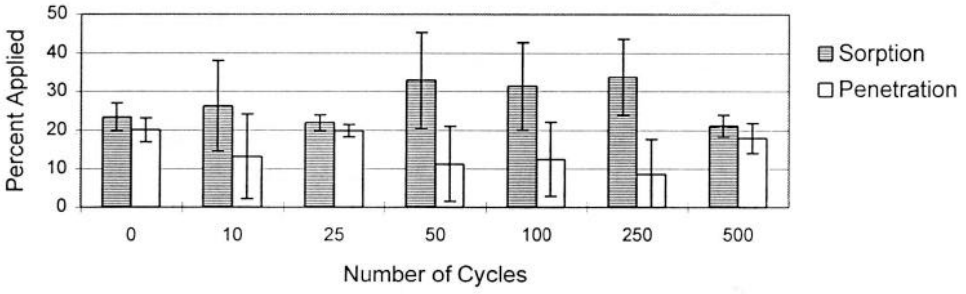

Figure 2. Sorption and penetration of metolachlor by/through abraded cotton/polyester fabrics with no finish (Note: Bars and error bars in Fig. 2-5 are means and SD, respectively.)

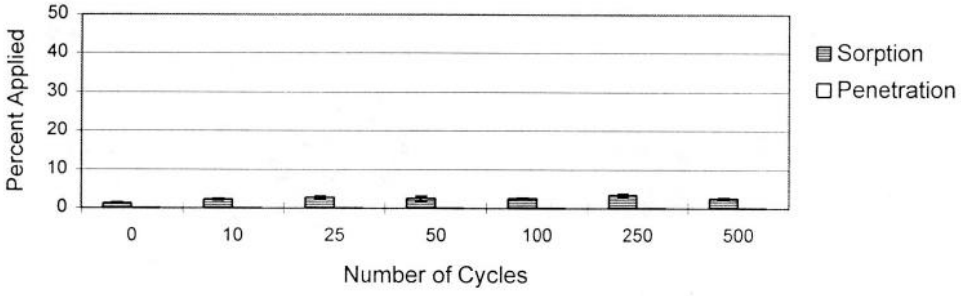

Figure 3. Sorption and penetration of metolachlor by/through abraded cotton/polyester fabrics with Zonyl® finish.

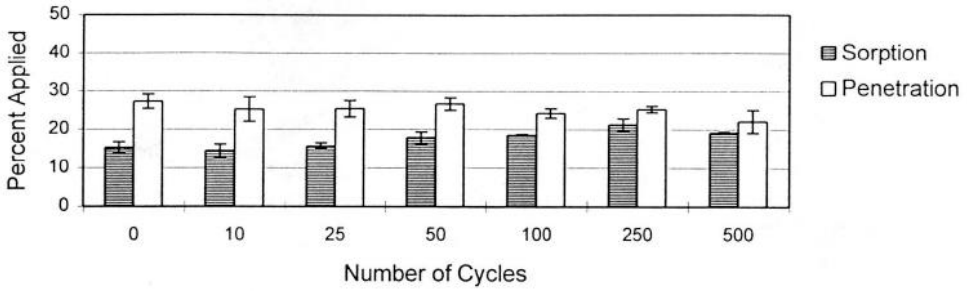

Figure 4. Sorption and penetration of metolachlor by/through abraded polyester fabrics with no finish

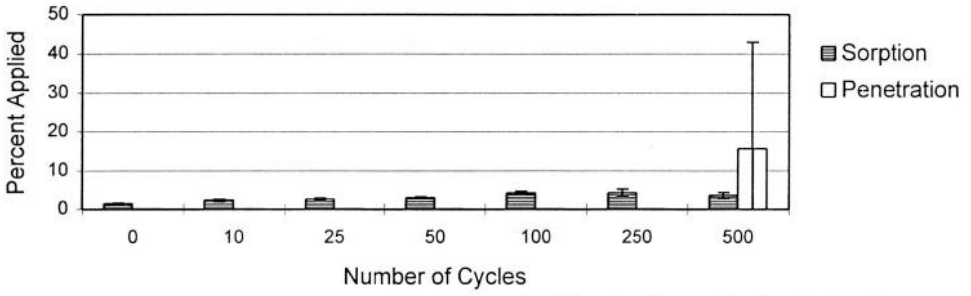

Figure 5. Sorption and penetration of metolachlor by/through abraded polyester fabrics with Zonyl® finish

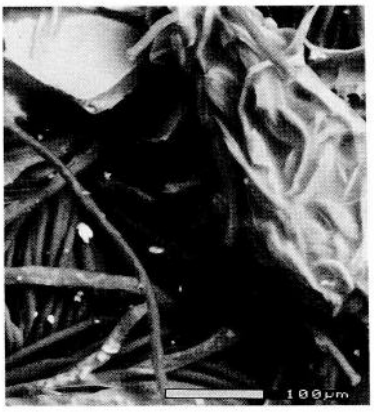

Figure 6. Cotton/polyester fabric illustrating pesticide retention in the entangled fibers on the surface of abraded fabric

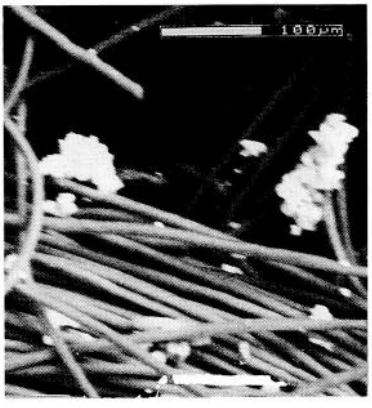

Figure 7. Polyester fabric showing large interyarn spaces with pesticide residue

illustrates pesticide retention in entangled fibers on the surface of fabric. The sorption and penetration at 0 and 500 cycles were similar. In general, the standard deviation for unfinished cotton/polyester fabrics was more due to fiber blend. The amount sorbed was consistently lower than the amount penetrated for all unfinished polyester fabric specimens. This was attributed to the fiber chemistry (hydrophobic fiber) and fabric geometry (open weave) and support study conducting by Raheel on pesticide penetration in fabrics (Raheel, 1988). As seen in Fig. 7, the interyarn space promoted the penetration of pesticide. Although the penetration patterns of unfinished cotton/polyester and polyester fabrics are different, the sorption patterns are similar. The sorption increases from 50 to 250 cycles, and then decreases at the 500 cycle level.

The sorption of pesticides was drastically reduced by the application of finish at all abrasion levels. The "masking effect" of inherent chemical properties and fabric porosity by fluorochemical finish (as discussed by Raheel, 1988) was evident even after 500 cycles abrasion. When compared, the finished cotton/poly performed better than polyester. The finished cotton/polyester fabric did not have detectable penetration at any abrasion level (Fig. 3). However, metolachlor did penetrate one finished polyester specimen after 500 abrasion cycles (Fig. 5). The SD for that set is very high because only one replication had a high penetration. Figure 8 micrographs show that finished fabric had pesticide on the surface of the fabric. Despite the concentration on the surface of the fabric, minimal or no pesticide penetrated to the back of the fabric, which indicated good barrier protection, but bright areas on the BE1 micrographs indicated presence of OsO_4 labeled pesticide. SEM analysis showed that the minimal penetration in the finished fabrics was generally through the interyarn space (Fig. 9).

Analysis of variance results show that for sorption and penetration, level of abrasion was not statistically significant at .01 level. Significant differences were seen between finished and unfinished fabrics, as well as cotton/ polyester and polyester fabrics (Tables 2 and 3). The fabric and finish two way interaction was also significantly different.

Table 2. Analysis of variance of percent pesticide sorbed by test fabrics.

Source	d.f.	F-Value	Prob. > F
Level of abrasion	6	1.86	0.0979
Fabric type	1	16.91*	0.0001
Finish	1	296.90*	0.0000
Abrasion * Fabric	6	0.66	0.6823
Abrasion * Finish	6	1.37	0.2413
Fabric * Finish	1	28.17*	0.0000

*Significant difference at 0.01 level

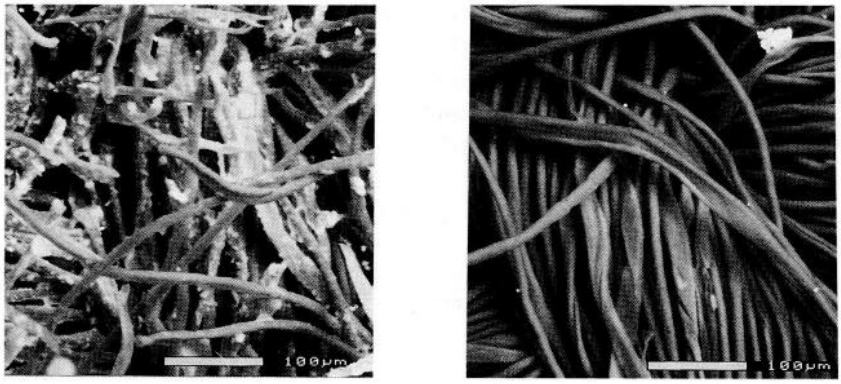

Figure 8. Backscatterred electron image of cotton/polyester fabric with zonyl finish after 100 abrasion cycles (Left: Face Fabric; Right: Fabric Back)

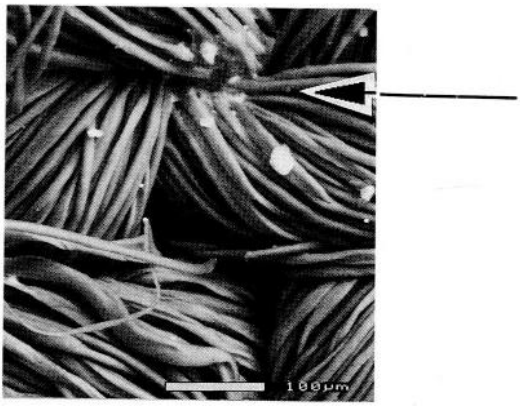

Figure 9. Back view of Zonyl® finished cotton/polyester fabric after 500 abrasion cycles illustrating penetration through interyarn spaces

Table 3. Analysis of variance of percent pesticide penetrated through to collector layers.

Source	d.f.	F-Value	Prob. > F
Level of abrasion	6	0.71	0.6413
Fabric type	1	23.66*	0.0000
Finish	1	350.34*	0.0000

*Significant difference at 0.01 level

The Zonyl® finish masked the effect of fiber chemistry and fabric geometry to a great extent. However, SEM micrographs indicated that some pesticide may penetrate finished fabrics through interyarn space. Based on the results of the study, it was concluded that Zonyl® finished fabrics provided good protection even after abrasion.

Acknowledgements. This study was a part of the USDA Cooperative Regional Research NC-170 Project. The authors thank the Agricultural Experiment Station, University of Maryland Eastern Shore, for financial support.

REFERENCES

Annual Book of ASTM Standards (1994) Textiles (II). American Society for Testing and Materials, vol 07.02. Philadelphia, PA. p 174-178

Laughlin J, Gold RE (1987) Methyl Parathion residue in cotton and polyester functionally finished fabrics after laundering and abrasion. Cloth Textiles Res J 5:9-17

Raheel M (1988) Pesticide penetration in fabrics: Fiber chemistry, surface energy, and fabric porosity. The first international symposium on the impact of pesticides, industrial and consumer chemicals on the near environment. Orlando, FL. February, 1988. p 127-136

Shaw A (1992) Effect of Zonyl® finish on the sorption and penetration of Diazinon by cotton, cotton/poly and polyester fabrics. Ninth Biennial Research Symposium of the Association of 1890 Research Directors. Atlanta, GA. October, 1992. p 101

Shaw A, Hill KR (1991) Effect of exposure time on the sorption of pesticide emulsifiable concentrates through microporous fabrics. Bull Environ Contam Toxicol 46:45-52

Shaw A (1991) New technique to label pesticide-contaminated fabrics for SEM analysis. Textile Research J 61:375-381