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Pesticide Transmission in Fabrics: Effect of Particulate Soil

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Current pesticide labeling requires prudent use of protective clothing when mixing, loading, and applying pesticide chemicals. Pesticide use and human health has been the subject of several investigations where findings suggest a cause-and-effect relationship (Laughlin 1988). Dermal exposure to pesticides is receiving much attention since it has been shown that dermal absorption accounts for 87% of the total human pesticide exposure (Gold et al. 1982, Maibach et al. 1971).

Much research activity has focused on the mechanism by which pesticides soil work clothing and the mechanism that enhances the removal of those chemicals from reusable clothing. Textile substrate variables such as fabric thickness (Kim et al. 1982), fiber morphology (Solbrig and Obendorf 1985), functional finishes (Raheel 1987b, Laughlin and Gold 1987, Laughlin et al. 1986), and detergency variables such as water temperature, water hardness, detergent type and concentration, and prewash additives (Easley et al. 1981, 1982; Easter and DeJonge 1985; Laughlin et al. 1985, 1986, 1987; Keaschall et al. 1986; Raheel 1987a) have been investigated. Furthermore, research efforts have been directed towards investigating the effects of fiber content, fabric geometry, and functional finishes of textiles on the barrier properties of commonly used work clothing (Raheel 1985, 1987b, 1988a, 1988b) and specialized protective clothing such as spunbonded, meltblown and composite polyolefins (Leonas et al. 1989, Crouse et al. 1990), and laminates using polytetrafluoroethylene (Branson et al. 1986). Nevertheless, there is scant literature on the effect of particulate soil (dust) on the movement of pesticide chemicals through apparel fabrics.

This study explores the movement of pesticide solutions through fabrics of various fiber contents, geometries, and functional finishes, in the presence and absence of particulate soil.

MATERIALS AND METHODS

Sixteen primary fabrics were studied for their pesticide

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transmission property. Fabric characteristics are given in Table 1. A 100% cotton knit T-shirt fabric served as a secondary collector substrate that absorbed the pesticide solution transmitted through the primary fabric. Fabrics were obtained from Testfabrics, Inc., Middlesex, NJ, except for the spunbonded olefin fabric which was contributed by E.I. du Pont Company. A test assembly consisted of the primary fabric measuring 8x8 cm, the collector fabric 7x7 cm (to avoid migration of pesticide from the edges of the primary fabric), and the third layer consisted of 8x8 cm of aluminum foil.

Table 1. Fabric characteristics

Fabrics	Fabric weight (g/m)	Fabric thickness (mm)	Yarns/cm W F	Yarn twist turns/cm W F
Primary				
100% Cot[a] UN[b]	295.0	0.495	33 x 24	7 x 5
100% Cot DP[c]	296.5	0.495	33 x 24	7 x 5
100% Cot SR[d]	295.1	0.495	33 x 24	7 x 5
#423 twill				
100% Cot UN	222	0.363	44 x 23	7 x 5
100% Cot DP	223	0.363	44 x 23	7 x 5
100% Cot SR	222	0.363	44 x 23	7 x 5
#407 poplin				
50/50 PET[e]/Cot UN	210	0.333	44 x 20	7 x 5
50/50 PET/Cot DP	210	0.337	44 x 20	7 x 5
50/50 PET/Cot SR	210	0.327	44 x 20	7 x 5
#7428 poplin				
65/35 PET/Cot UN	180	0.274	44 x 23	7 x 5
65/35 PET/Cot DP	183	0.274	44 x 23	7 x 5
65/35 PET/Cot SR	180	0.274	44 x 23	7 x 5
#7402 poplin				
100% PET #767 plainweave	116	0.236	25 x 19	8 x 7
100% Nylon #361 plainweave	150	0.325	21 x 23	6 x 8
100% Acrylic #864 plainweave	140	0.325	19 x 5	5 x 5
100% Olefin Spunbonded (Tyvek®)	40	0.091	---	---
Secondary				
100% Cotton, knit	150	0.480	---	---

[a]Cot = Cotton, [b]UN = Untreated, [c]DP = Durable press, [d]SR = Soil-repellent, [e]PET = Polyester.

One set of primary fabrics (3 specimens per replication and three replications) was soiled with dust and the other set was kept clean. Since it is the fine dust particles which become airborne and settle on work clothing, dust of < 150 μm particle size was used. Particulate soil was passed through a 60-mesh screen, and then a 100-mesh screen to remove lint and coarse particles. It was then autoclaved at 125°C for 30 minutes and air dried. Dust was applied to fabric specimens at 5% OWF individually, according to Kissa's method (1971). An Accellerotor type AB7 without abrasive liner was used. Excess soil was removed from the specimen by stroking a brush once in the warp and once in the weft direction.

The layered fabric assembly was contaminated with 1 mL of 1.25% (a.i) pesticide solution according to the method described by Raheel (1988[a]). Two pesticides were used for contaminating the fabrics: carbaryl, in wettable powder (Sevin® 50W) and flowable liquid (Sevin® 4L) formulations, and atrazine, also in wettable powder (Aatrex® 80W) and flowable liquid (Aatrex® 4LC) formulations. Transmitted pesticide was extracted from the collector fabric as described by Raheel (1987b). Residue analysis was done by gas chromatographic technique as described by Raheel (1988[b]), using technical grade carbaryl and atrazine as external standards. Extraction efficiency tests indicated that recovery of carbaryl was 87% and atrazine was greater than 90%.

Analysis of variance and F-ratios were used to detect significant differences in pesticide transmittance through fabrics at $\alpha \leq 0.05$. Separation of means was achieved with Least Significant Means and Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

ANOVA results (Table 2) indicated that fabrics were significantly different ($\alpha \leq 0.05$) in their ability to transport pesticide

Table 2. ANOVA of the effect of fabric, pesticide and treatment variables on pesticide transmission

Effect	Degrees of freedom	F-ratio	p > F value
Fabrics (F)	15	19.52	0.0000
Treatments (T)[a]	1	54.40	0.0000
F x T	15	59.85	0.0000
Pesticides (P)	3	28.84	0.0001
P x F	45	17.57	0.0000
P x F x T	45	11.68	0.0018

[a]T = No treatment, particulate soil treatment.

solutions. The presence of particulate soil on the fabrics reduced pesticide transmission significantly. In addition, the pesticides (type and formulation) exhibited significantly different levels of transmission through the fabrics.

Quantitative data for the transmission of carbaryl, in wettable powder and flowable liquid formulations, are given in Table 3, whereas Table 4 presents the data for atrazine transmission. Duncan's groupings are shown along with quantitative data. It is clear from Tables 3 and 4 that pesticide transmission was reduced in the order of three to tenfold from dust-soiled fabrics compared to the unsoiled ones. Nevertheless, the general trend of pesticide transmission remained a function of fabric type, fiber content and functional finishes. That is, the spunbonded olefin fabric (Tyvek®) and the repellent finished fabrics exhibited the lowest level of transmission. These were followed by 100% cotton and cotton/polyester blend fabrics, whereas woven fabrics made of 100% synthetic fibers exhibited high levels of pesticide transmission. Furthermore, the presence of dust masked the differences between 100% cotton and cotton/polyester blend fabrics. Thus 100% cotton, cotton/polyester blends (50/50 and

Table 3. Effect of particulate soil on the amount of carbaryl[a] ($\mu g/cm^2$) transmitted from primary fabric[b] to the secondary fabric

Primary fabric	Transmitted pesticide ($\mu g/cm^2$)							
	Wettable powder				Flowable liquid			
	N[c]	DM[d]	S[e]	DM	N	DM	S	DM
100% Cot (UN)	10.10	A	2.10	A	10.75	A	2.70	A
100% Cot (DP)	10.25	A	2.00	A	10.80	A	2.65	A
100% Cot (SR)	0.45	A	0.04	A	0.42	A	0.06	A
(twill)								
100% Cot (UN)	12.45	A	1.95	A	16.15	AB	2.10	A
100% Cot (DP)	12.60	A	1.90	A	16.40	AB	2.15	A
100% Cot (SR)	0.42	A	0.05	A	0.45	A	0.06	A
(poplin)								
50/50 PET/Cot (UN)	16.90	AB	2.24	A	20.65	BC	2.61	A
50/50 PET/Cot (DP)	16.75	AB	2.10	A	24.10	BC	2.75	A
50/50 PET/Cot (SR)	0.09	A	0.05	A	1.05	A	0.06	A
65/35 PET/Cot (UN)	27.10	BC	2.98	A	27.13	BC	3.15	A
65/35 PET/Cot (DP)	28.85	BC	3.24	A	26.50	BC	3.16	A
65/35 PET/Cot (SR)	0.05	A	0.05	A	1.40	A	0.07	A
100% Polyester	101.70	F	38.15	C	102.40	E	39.10	C
100% Nylon	82.50	D	32.34	B	79.99	D	31.91	B
100% Acrylic	96.20	E	32.56	B	95.00	D	32.88	B
100% Olefin (Spunbonded)	0.04	A	0.01	A	0.07	A	0.01	A

[a] = Mean of nine values, [b] = The primary fabrics were treated with 280 $\mu g/cm^2$ pesticide, [c]N = No treatment, [d]DM = Duncan's Multiple Range Grouping, [e]S = Particulate soil treatment.

65/35), and repellent finished (SR) fabrics fell in the same Duncan's grouping as the spunbonded olefin (Tyvek®) protective garment fabric. Although the level of transmitted pesticides was high for polyester, nylon and acrylic fabrics, nonetheless it was significantly lower than the unsoiled fabrics. These trends were noted for both pesticides--carbaryl and atrazine, in wettable powder as well as liquid formulations. In general, a greater amount of atrazine was transmitted compared to carbaryl. Also, compared to wettable powder formulation, a relatively higher level of liquid formulation was transmitted through fabrics.

Table 4. Effect of particulate soil on the amount of atrazine[a] ($\mu g/cm^2$) transmitted from primary fabric[b] to the secondary fabric

Primary fabric	Transmitted pesticide ($\mu g/cm^2$)							
	Wettable powder				Flowable liquid			
	N[c]	DM[d]	S[e]	DM	N	DM	S	DM
100% Cot (UN)	13.95	A	2.90	A	16.98	A	2.89	A
100% Cot (DP)	13.98	A	3.15	A	16.99	A	3.25	A
100% Cot (SR) (twill)	2.97	A	0.15	A	4.90	A	0.17	A
100% Cot (UN)	20.75	AB	2.98	A	24.20	AB	3.91	A
100% Cot (DP)	20.80	AB	2.99	A	24.10	AB	3.89	A
100% Cot (SR) (poplin)	0.51	A	0.05	A	0.75	A	0.06	A
50/50 PET/Cot (UN)	27.90	BC	2.99	A	31.10	BC	4.17	A
50/50 PET/Cot (DP)	28.60	BC	2.98	A	36.50	BC	4.18	A
50/50 PET/Cot (SR)	0.98	A	0.06	A	1.61	A	0.07	A
65/35 PET/Cot (UN)	60.70	BC	3.75	A	62.19	BC	4.71	A
65/35 PET/Cot (DP)	60.98	BC	3.76	A	66.12	BC	4.89	A
65/35 PET/Cot (SR)	0.45	A	0.05	A	0.48	A	0.07	A
100% Polyester	149.90	D	44.98	C	168.80	F	42.71	C
100% Nylon	122.70	C	32.91	B	95.75	D	38.12	B
100% Acrylic	121.91	C	32.90	B	142.61	E	39.64	BC
100% Olefin (Spunbonded)	0.09	A	0.01	A	0.09	A	0.01	A

[a] = Mean of nine values, [b] = The primary fabrics were treated with 280 $\mu g/cm^2$ pesticide, [c]N = No treatment, [d]DM = Duncan's Multiple Range Grouping, [e]S = Particulate soil treatment.

It is hypothesized that dust particles not only blocked the interstices (or pores) in the fabrics, thus interrupting capillary flow of pesticide solutions, but also acted as reservoirs and absorbed a substantial amount of pesticide, thus reducing transport through the fabrics. In agricultural settings, garments are liable to become contaminated with particulate soil while workers are engaged in pesticide handling and application activities. Dust-soiled garments may in fact trap pesticides to a degree and provide a measure of dermal protection. It is of interest, however, to study the degree of pesticide removal in laundering, when garments have been soiled with particulate soil in conjunction with pesticides.

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