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Preliminary Evaluation of Nonwoven Chemically Treated Barrier Fabrics for Field Testing of Protective Clothing for Agricultural Workers Exposed to Pesticides

B. G. Oakland,[1] R. B. Dodd,[2] D. J. Schabacker,[1] and L. X. Clegg[1]

[1]Department of Clothing and Textiles, The University of North Carolina at Greensboro, Greensboro, North Carolina 27412, USA and [2]Department of Agricultural and Biological Engineering, Clemson University, Clemson, South Carolina 29634-0357

The U.S. Environmental Protection Agency has proposed regulations to require specific pesticide labelling requirements for protective equipment for agricultural workers which may become mandatory. The label must designate acceptable protective clothing for specific end use conditions. This increases the importance of prescreening test fabrics as chemical barriers to pesticide penetration before field exposures studies, which are time consuming and expensive, are conducted. Much work remains to be done to provide optimum protection for agricultural workers exposed to pesticides.

The purpose of this research was to evaluate chemically treated barrier fabrics for comfort, durability, and resistance to spray penetration of pesticides.

MATERIALS AND METHODS

Physical tests were run to prescreen nonwoven fabrics as candidates for further tests. Based on the data for weight, thickness, abrasion, air permeability, Elemendorf tear tests, and wet and dry tensile strength, five nonwoven fabrics were selected to be tested. The fabrics selected included unfinished "Tyvek" 1422A, Regular, "Sontara", "Sontara FC", and "SMS" with and without a repellent finish. SMS is a spunbonded polyethylene fabric and Sontara is a wood pulp polyester spunlaced fabric.

The Sontara is made of polyester staple and a layer of wood tissue paper. The pulp fibers are hydrophilic and the polyester is hydrophobic. Thus, the pulp fibers enhance the barrier properties by taking the repellent finishes well. Both unfinished Sontara and Sontara with a fluorocarbon finish were included in the study.

The SMS fabrics made by Kimberly-Clark Corporation were laminates of spunbonded/meltdown/spunbonded webs of polypropylene. The Tyvek and Sontara were made by DuPont.

Send reprint requests to Dr. Billie Oakland at the above address.

Three formulated pesticides were used in this study of fabric efficacy against pesticide penetration. These included two herbicides--AAtrex 4L (4 lb. a.i. atrazine/gallon), Dual 8E (8 lb. a.i. metolachlor/gallon), and an insecticide--D·Z·N Diazinon AG500 (4 lb. a.i. diazinon/gallon). The three formulations were used at field strength, 1.25% active ingredient, with and without sodium fluorescein dye tracer. The dye tracer was used to obtain preliminary information on the use of sodium fluorescein as an indicator of pesticide penetration. This work will be reported in detail in a later publication. The concentrations of the active ingredient and dye tracer in the spray solution were 1.25% and 0.0125%, respectively.

Clemson University, in cooperation with the University of North Carolina at Greensboro, developed a spray system that generates a fine reproducible spray mist on test specimens placed on stainless steel vertical arms (Dodd, et. al., 1988), allowing the sample to be sprayed similar to field conditions. The spray mist is generated by a horizontally moving nozzle with a 1.25 minute cycle. Nozzle P/N 650017 (Spraying Systems, Inc.) was chosen to create a fine droplet simulating field conditions. The application rate was 45 ml/min at 50 psi and 65 ml at 70 psi. The barrier fabrics were mounted over 3" x 3" gauze patches which absorbed the spray that penetrated the fabrics. The penetration tests were conducted at pressures of 50 and 70 psi, and the speed was the same in both directions. A diagram of the spray apparatus is shown in Figure 1.

The carriers for the spray tests were: (1) water and sodium fluorescein dye, (2) atrazine and water, (3) atrazine/water/dye (4) metolachlor and water, (5) metolachlor/water/dye, (6) diazinon and water, and (7) diazinon/water/dye. The herbicides and the insecticide as supplied contained surfactants. The residue of the sodium-fluorescein dye in a water carrier was measured quantitatively with spectroscopic analysis. The sodium-fluorescein dye and pesticide formulation residues were separated by partitioning the extract between water and solvent, and each extract was analyzed for the respective constituent with spectroscopic and gas chromatographic techniques.

The physical properties related to comfort and durability were measured according to standard test measures given in Table 1.

RESULTS AND DISCUSSION

The physical characteristics are summarized in Table 2. They were measured to compare properties related to product performance such as abrasion and wet and dry strength for durability or air permeability as an indicator of comfort. Their relationship to spray penetration is also important.

The Sontara fabric with a fluorocarbon finish had the highest air permeability values (67.3 $ft^3/min/ft^2$), the finished SMS was second (11.6 $ft^3/min/ft^2$) while

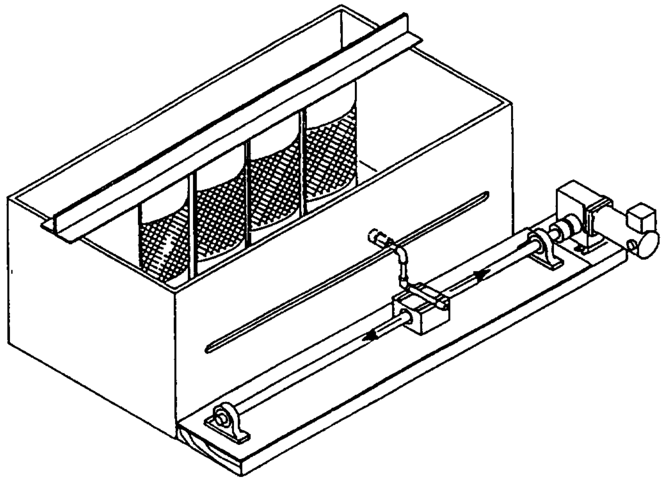

Figure 1. Spraybox for fabric evaluations

Table 1. Standard test methods for physical performance of nonwoven barrier fabrics.

Physical Properties	Standard Methods
Weight	INDA IST 130.070 (R77) from ASTM D-1910-64
Thickness	INDA IST 1200-70 (R82) from ASTM D-1744-64
Air Permeability	INDA IST 70.0 - 70 (R77) from ASTM D737-75
Abrasion (Dry)	ASTM D 3886-80
Breaking Strength (Wet and Dry)	INDA IST 110.0 - 70 (R77) from ASTM D-1682-64

Tyvek had zero air permeability. The air permeability was greater for the Sontara FC and the SMS with repellent finish than for the unfinished fabrics.

The Sontara FC is stronger (13.7 kg) than SMS with a repellent finish (11.8 kg) or Tyvek (9.2 kg). The wet strength is less than the dry strength for both Sontara FC and SMS with a repellent finish. The coefficients of variation for the physical tests ranged from 1 to 56% and are indicators of the wide variation of the nonwoven fabrics. This agrees with the findings reported by Wadsworth (1988), and it means that the physical testing data is useful primarily for ranking the test fabrics.

Table 2. Physcial properties of five nonwoven test fabrics with and without repellent finishes[1]

	TYVEK	SONTARA		SMS	
	1422A	Unfinished	FC	Unfinished	
Repellent Finish	Regular		Finish		
Weight (oz/yd²)	1.26	2.0	2.11	2.43	2.45
(g/m²)	42.73	67.82	71.55	82.40	83.08
Thickness (in)	.008	.010	.013	.017	.015
(mm)	.19	.25	.33	.42	.38
Abrasion					
Inflated diaphragm	44.00	198.00	69.00	111.60	167.20
Air permeability					
(ft³/ft²/min)	0.00	58.70	67.30	8.30	11.60
(cm³/cm²/min)	0.00	1789.20	2051.30	253.00	353.57
Elemendorf tear test (kg)					
(MD)	2.75	1.61	1.95	2.17	1.86
(CD)	2.47	2.28	2.41	2.08	1.82
Liquid wicking (mm)	none	90.67	none	none	none
Time		6.46			
Tensile strength (kg)					
Grab (dry)					
(MD)	9.18	17.57	13.75	13.36	11.76
(CD)	9.62	8.46	8.01	13.21	10.48
Elongation (%)					
(MD)	18.81	22.27	33.22	31.25	18.86
(CD)	25.00	73.61	78.19	30.56	26.99
Grab (wet)					
(MD)	10.03	10.67	11.77	11.83	11.12
(CD)	12.27	5.07	6.18	11.93	9.37
Elongation (%)					
(MD)	10.78	72.79	87.27	103.49	58.08
(CD)	13.90	198.99	196.52	91.51	92.35

[1] Mean of five replications

At a spray cycle of 1.25 min, with 50 and 70 psi, atrazine, diazinon and metalachlor with or without the tracer, exhibited no penetration through Tyvek 1422A, Sontara FC, or SMS with a repellent finish. The Sontara FC and SMS with a repellent finish failed when tested with a continuous spray at seven and ten minutes, respectively. This is noted in Table 3.

Table 3. Continuous spray penetration characteristics of tyvek 1422, sontara FC, and SMS with a repellent finish atrazine and sodium-fluorescein dye at 2, 5, 7, 10, 15 minute intervals (50 psi)[1]

Time	Penetration ($\mu g/cm^2$) Tyvek		Sontara FC		SMS	
	Atrazine	Dye	Atrazine	Dye	Atrazine	Dye
2 min.	<10	<2	<10	<2	<10	<2
5 min.	<10	<2	<10	<2	<10	<2
7 min.	<10	<2	6,643	202	<10	<2
10 min.	<10	<2	32,417	646	627	<2
15 min.	<10	<2	40,947	1,281	48,876	859

[1] mean of five replications

The pesticide and fabric interaction for the three fabrics is shown in Figure 2. There is a significant interaction at the .01 level between fabric and pesticide. The protective properties of the fabrics are a function of the pesticide formulation. The pesticide and pressure interaction is shown in Figure 3 for three pesticides at two pressures. It was significant at the .01 level. The pesticide penetration varied by pressure and pesticide formulation.

Five nonwoven fabrics were evaluated for comfortable and chemically resistant protective clothing for agricultural workers exposed to pesticides. The coefficients of variation were high for both the physical properties and the spray penetration tests. This appeared to be due to the variation in the test materials and test methods.

The barrier fabrics vary in properties associated with comfort and durability as well as resistance to pesticide penetration. It is not possible to generalize from this data for other conditions and formulations. But the spray procedure previously described is very useful to prescreen and identify nonwoven fabrics as candidates for chemically barrier fabrics to be used in the field evaluation of protective clothing.

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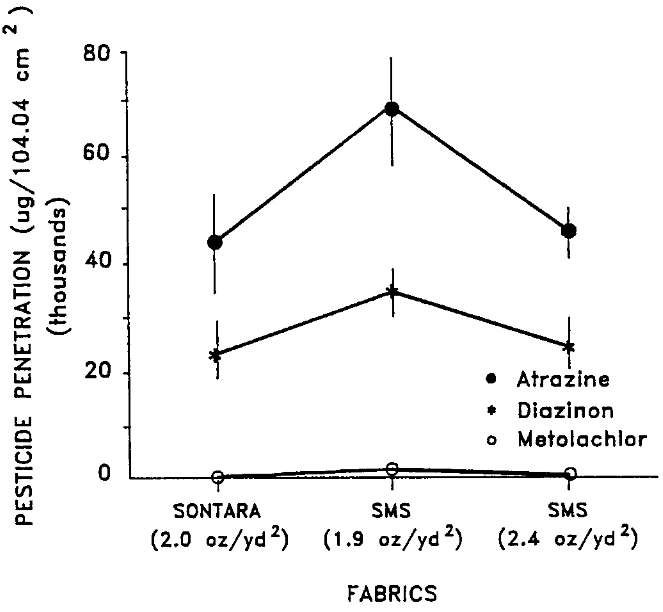

Figure 2. Interaction between pesticides penetration and fabrics

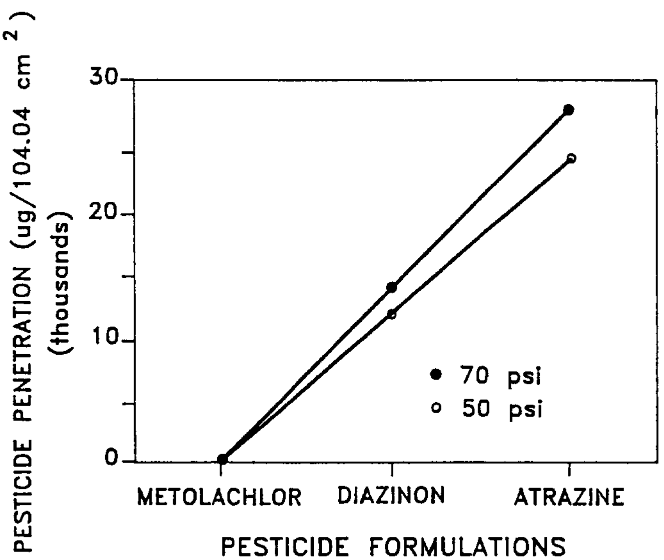

Figure 3. The relationship between pesticide penetration and pressure

REFERENCES

Dodd, RB, Oakland, BG, McClaskey, B.(1988, February). Simulation of field conditions during pesticide application for fabric evaluation. In Reagan, BM, Johnson, D, and Dusaj S (eds) Proceedings of the First International Symposium on the Impact of Pesticides, Industrial and Consumer Chemicals on the Near Environment. Orlando, FL, pp 88-93

Hobbs NE, Oakland BG, Hurwitz MD (1986). Effects of barrier finishes on aerosol spray penetration and comfort of woven and disposable nonwoven fabrics for protective clothing. In Barker RL, Coletta GC (eds) Performance of protective clothing ASTM STP 900, American Society for Testing Materials, Philadelphia, pp 151-161

Leonas, KK, DeJonge JO, and Duckett KE (1978). Development and validation of a laboratory pesticide spray system for fabric penetration evaluation, In Mansdorf SZ, Sager R, Nielson AP (eds) Performance of Protective Clothing: Second symposium, ASTM STP 989, American Society for Testing Materials, Philadelphia, pp 660-670

Wadsworth LC, Easter EP, and Lin YQ (1988, February). A study of nonwoven fabrics in providing repellency and barrier performance, In Reagan BM, Johnson D, and Dusajs (eds) Proceedings of the First International Symposium on the Impact of Pesticides, Industrial and Consumer Chemicals on the Near Environment. Orlando, FL, pp 137-153

Worker Protection Standards for Agricultural Pesticides; public meeting and proposed rule: July 8, 1988 Federal Register, 40, No. 131, p. 25983.

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