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Recommendations for Selecting and Decontaminating Pesticide Applicator Clothing[1]

Thomas H. Lillie,[2] James M. Livingston,[3] and Mark A. Hamilton[2]

[2]USAF Occupational and Environmental Health Laboratory, Environmental Assessment Branch, Brooks AFB, TX 78235 and [3]USAF Aerospace Medical Research Laboratory, Wright-Patterson AFB, OH 45433

The clothing worn by pesticide applicators is subjected to contamination by both concentrated and dilute pesticide solutions during routine mixing and application activities. Significant levels of pesticide residues in worker clothing have been reported (FINLEY & ROGILLIO 1969; WARE et al. 1973). Little work has been done in comparing the resistance of different fabrics to penetration by insecticide solutions or in evaluating decontamination procedures.

WARE et al. (1973) concluded that even though large amounts of parathion residue were deposited on cotton denim jeans, little penetration was achieved. FINLEY et al. (1977) found that 100% cotton clothing retained less methyl parathion than 50/50 cotton polyester blend clothing. They also found that one washing removed most methyl parathion residues and two washings were even more effective.

Pesticide residue in contaminated clothing can be reduced with home laundering techniques (FINLEY et al. 1974; SATOH 1979); however, it is not advisable to wash such material with the family wash (KARCHES et al. 1977). FINLEY et al. (1974) have shown that DDT, toxaphene, and methyl parathion residues in contaminated clothing remain toxic to living organisms, even after the clothing has been subjected to repeated washings. Specific procedures for decontaminating the clothing of workers exposed to methyl parathion have been published. Under such procedures, the recommended washwater temperature is 60°C or higher (FINLEY et al. 1977), but no justification was provided for that temperature. The Department of Energy has recommended a maximum temperature setting of 40°C to conserve energy for general purpose hot water lines (Federal Register 1979).

We evaluated the absorption and penetration qualities and the washability of 100% cotton fabric and 100% polyester fabric.

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Physical properties of the two fabrics are given in Table 1. We also conducted tests to determine the effects of washwater temperature on decontamination of the 100% cotton fabric.

TABLE 1

PHYSICAL PROPERTIES FOR POLYESTER AND COTTON FABRICS

Fabric	Weight (minimum) (oz/sq yd)	Yarns/in (minimum) Warp	Filling	Breaking Strength (lbs) (minimum) Warp	Filling
Polyester	2.8	74	62	155	135
Cotton	9.0	85	48	115	100

MATERIALS AND METHODS

Washing Procedures

The absorption, penetration and washability of both the 100% cotton and 100% polyester fabrics were tested with the insecticides diazinon (O,O-diethyl O-[6-methyl-2-(1-methylethyl)-4-pyrimidinyl] Phosphorothioic acid), chlordane (1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-Methano-1H-indene; and related compounds), and carbaryl (1-Naphthalenol, methylcarbamate) and the herbicide prometon (6-methoxy-N,N'-bis(1-methylethyl)-1,3,5-Triazine-2,4-diamine). Insecticide preparations of 0.5% diazinon were prepared from 47.5% commercially formulated emulsifiable concentrate (EC), 1.0% chlordane from 71.5% EC; and 0.25% carbaryl from a 50% wettable powder formulation. A 25% EC prometon formulation was used to prepare a 2.5% concentration.

The effects of washwater temperature on the removal of pesticide residue from clothing was evaluated for the 100% cotton fabric only. The technical grade pesticides malathion ([(dimethoxyphosphinothioyl)thio]-Butanedioic acid) (91.5%), bromacil (5-bromo-6-methyl-3-(1-methylpropyl)-2,4(1H,3H)-Pyrimidinedione) (21.9%), diazinon (47.5%), chlordane (71.5%), and propoxur (2(1-methylethoxy)-phenolmethylcarbamate)(13.9%) were tested. The malathion and bromacil were oil formulations while all others were EC's. Dilute solutions of diazinon (0.5%), chlordane (1.0%), and propoxur (1.1%) were also prepared for testing.

For all tests, the fabrics were cut into 5x5 cm samples and 1 ml of a given pesticide was pipetted, using a 10 ml disposable glass pipet, directly onto each cloth sample in a manner which prevented runoff from the cloth edges. This method of application was intended to simulate a splash or spill on the material. The cloth samples were placed on filter paper for the penetration tests and these and all other samples were backed by aluminum foil. The treated samples were allowed to air dry for 24 h following treatment. Four samples of each pesticide and four blanks (untreated cloth samples) were prepared for each test.

After the pesticide preparation had dried, the pesticide residue was extracted from the cloth samples and filter paper and analyzed to complete the absorption and penetration tests. Samples for the washability test for a single pesticide were washed together in a normal warm (43°C) water wash cycle. A one-speed Whirlpool^R washing machine operating at 68 agitations per min was used. Fifty g (1/2 cup) of laundry detergent was added to each wash. The detergent was a nonphosphorus product which contained sodium carbonate, sodium sulfate, silica, and a trace of alkyl aryl sulfonate. The pH of a 1% solution of the detergent was approximately 11. After a 14-min wash followed by two rinses (35-min total time), the samples were dried for 30 min in a Whirlpool ^{R} gas dryer. The samples were then individually wrapped in aluminum foil and placed in refrigerated storage (5°C) prior to analysis.

This washing procedure was also followed for evaluating the effects of washwater temperature on the removal of pesticide residue from the 100% cotton fabric. Four replicates for each pesticide were washed together in cold (30°C), warm (43°C), or hot (60°C) water. These samples were also dried for 30 min in a gas dryer, wrapped in aluminum foil, and stored at 5°C.

Analytical Procedures

The bromacil samples were soaked for 30 min in 100 ml of methanol while all other pesticide samples were soaked for the same duration in 100 ml of pesticide grade hexane. The solution was then analyzed by either gas chromatography or ultraviolet absorption.

An external reference solution of each pesticide was used as a standard for all analyses. The type of detector was dependent upon the analyst's preference and the chemical structure of a given pesticide. This resulted in the use of different detectors and different columns for analyzing the same pesticide during different phases of the study (Table 2). All procedures were in accordance with EPA guidelines (BONTOYAN 1976). A 5 µl injection volume was used on the gas chromatographic instruments.

TABLE 2

SUMMARY OF ANALYTICAL APPARATUS

Test(s)	Pesticide(s)	Detector	Detection Limit	Sensitivity	Columns
Penetration, Absorption, and Washability	Carbaryl, Chlordane, and Diazinon	Electron Capture	20 μg	±20 μg	1.5% OV 17/1.95% OV-210 Chrom W and
	Prometon	Electrolytic Conductivity	1.2 mg	±1.2 mg	4% SE 30/6% OV-210 Chrom W
	Diazinon and Malathion	Flame Photometric	0.2 μg	±0.2 μg	5% OV-210 on 80/100 Gas Chrom Q
Wash Temperature	Chlordane and Bromacil	Electron Capture	0.04 μg	±0.04 μg	3% Dexsil 300 on 80/100 Chrom W/AW
	Propoxur	Ultraviolet	50 μg	±50 μg	

RESULTS AND DISCUSSION

Differences in penetration between cloth materials and pesticides are apparent (Table 3). The results were compared using an analysis of variance (ANOVA). A significantly greater amount of pesticide ($p = 0.01$) penetrated the 100% polyester fabric than the 100% cotton fabric. Further analysis of these data for each pesticide was performed using Duncan's multiple range test (STEEL and TORRIE 1960). The difference was significant ($p = 0.05$) for all pesticides except carbaryl. With chlordane, over 2.8 times more insecticide penetrated the polyester than the cotton, and with diazinon over 5.2 times more insecticide penetrated the polyester than the cotton. The same general pattern was observed with prometon. The lack of difference in penetration of carbaryl was probably due to its formulation as a wettable powder. The particles were large enough to be trapped on the surface of the polyester, therefore, little penetration was achieved.

TABLE 3

MEAN ABSORPTION AND PENETRATION (mg) ± STANDARD ERROR AND REMOVAL OF PESTICIDES IN 100% COTTON AND 100% POLYESTER FABRICS

	Absorption		Penetration		Wash Removal
Material	mg	%	mg	%	%
chlordane					
cotton	9.2 ± 0.6	76	3.0 ± 0.2	25	91
polyester	3.0 ± 0.4	32	6.2 ± 0.5	68	89
diazinon					
cotton	3.3 ± 0.3	87	0.50 ± 0.03	13	95
polyester	1.2 ± 0.1	30	2.6 ± 0.2	70	99+
carbaryl					
cotton	2.4 ± 0.2	99	Trace	Trace	99+
polyester	2.6 ± 0.3	93	0.21 ± 0.03	7	99+
prometon					
cotton	18.3 ± 0.3	98	1.22 ± 0.02	2	99+
polyester	2.2 ± 0.2	13	14.6 ± 0.6	87	99+

The absorption of pesticide by each fabric was inversely proportional to the penetration (Table 3). The amount of chlordane, diazinon, and prometon absorbed by the polyester fabric was significantly ($p = 0.05$) less than that absorbed by the cotton (Duncan's Multiple range test). Our data differ from FINLEY et al. (1977) in that the cotton absorbed much more than did the polyester.

There was no significant difference ($p = 0.05$) in the amount of pesticide residue remaining in the two fabrics after washing when the results were compared using Duncan's multiple range test (Table 3). Chlordane removal was about the same for both materials while polyester washed cleaner than cotton after diazinon application. Carbaryl and prometon were readily removed from both materials.

A significant amount ($p = 0.01$; ANOVA) of pesticide residue was removed from the 100% cotton fabric regardless of washwater temperature (Table 4). There was a tendency for increased residue removal with increased temperature but the difference was not significant ($p = 0.05$) for all pesticides when these data were compared using Duncan's multiple range test.

TABLE 4

PERCENTAGE OF PESTICIDE RESIDUE REMOVED FROM CLOTH SAMPLES BY WASHING IN COLD (30°C), WARM (43°C), AND HOT (60°C) WASH WATER

Pesticide	(%)	% Removed by Wash		
		Cold	Warm	Hot
Diazinon	(47.5)	85	a	96
	(0.5)	68	79	99
Propoxur	(13.9)	82	99+	ND
	(1.1)	ND	ND	ND
Chlordane	(71.5)	99+	96	98
	(1.0)	63	52	56
Bromacil	(21.9)	90	97	99+
Malathion	(91.5)	93	95	97

ND = No residue detected
a = analytical error

Diazinon removal was the most sensitive to changes in water temperature (Table 4). For the concentrated material, 85% of the residue was removed in the cold treatment whereas 96% was removed in the hot treatment. The effect of water temperature was more noticeable for the dilute solution. The amount of residue removed by the hot water wash (99%) was significantly greater ($p = 0.05$) than the amount removed by the cold (68%) or warm (79%) water treatments.

The degree of propoxur removal was also influenced by water temperature (Table 4). The amount removed varied from 82% in the cold water to over 99% in the warm water. This difference was statistically significant ($p = 0.05$). The amount of propoxur residue, if any, remaining in the hot water samples was below the detection limit. Essentially all of the propoxur residue was removed by the washing process for all samples treated with the dilute solution.

The pesticides bromacil and malathion followed the same trend of increased residue removal with increased temperature (Table 4). The results, however, were not significantly different ($p = 0.05$) when these data were compared using Duncan's multiple range test. The primary factor contributing to a lack of significant difference was that over 90% of the residue from both pesticides was removed by all wash temperatures.

The effects of washwater temperature on chlordane removal did not follow the trend observed for other pesticides (Table 4). Chlordane was more stable with regards to water temperature. The persistence of chlordane, as well as many other organochlorine insecticides, is well documented. The blank (untreated) cloth samples were even found to be contaminated with chlordane. The degree of contamination ranged from 1 to 17 μg of chlordane when 16 blank samples were examined. The mean contamination rate was 7.4 μg/blank.

We have found the 100% cotton fabric superior to 100% polyester in affording protection to pesticide applicators. The cotton offers greater resistance to penetration by pesticides. We also found that there is a trend toward increased pesticide residue removal from 100% cotton with increased washwater temperature. We recommend that the washwater temperature be $\geq 60°C$ to achieve maximum decontamination of pesticide applicator clothing.

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