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Removal of Pesticide Residues as Affected by Laundering Variables

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Pesticide residues are picked up by farm clothing worn during pesticide applications. When the clothing comes in contact with skin, the residue can be absorbed into the body (WOLFE et al. 1967), causing skin irritation as well as other more serious symptoms. Appropriate care methods for contaminated farm clothing need to be identified to reduce the risk of pesticide exposure.

FINLEY & ROGILLIO (1969) examined the effectiveness of laundering for removing DDT and methyl parathion residues and noted that DDT was not removed efficiently by laundering although the amount of methyl parathion was significantly reduced. FINLEY et al. (1974) found that methyl parathion alone was more effectively removed than when applied with toxaphene and DDT. These findings indicate that pesticide types play a role in laundering effectiveness. FINLEY et al. (1974) suggested possible interaction between pesticide type and detergent by stating that alkalinity of the detergent might have caused the easier removal of methyl parathion since it hydrolizes in an alkaline medium.

EASLEY et al. (1981) reported that methyl parathion removal in cotton and cotton/polyester fabrics was greater when pre-rinse preceded detergent washing than when only detergent or detergent plus bleach or ammonia additive was used. They also attributed methyl parathion removal to the effect of detergent alkalinity. LAUGHLIN et al. (1981) reported that pesticide residues in fabrics after laundering were biologically active, but that residues transferred to uncontaminated fabrics through laundering did not cause cockroach mortality.

To conserve energy, consumers are now encouraged to launder clothing at as low temperatures as possible. Use of lower wash temperature may adversely affect removal of pesticide residues. EASLEY et al. (1982 in press) found no significant difference in residue removal between hot wash ($60^{o}C$) and warm wash ($49^{o}C$), whereas cold wash ($30^{o}C$) produced significantly lower removal of parathion residues. However, this conclusion remains to be tested with other pesticide types. They suggested further investigation into the relationships between wash-water temperature, detergent, pesticide formulation, and effects of multiple washings.

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A survey of literature related to the use of pesticide revealed no research concerning the removal of pesticides commonly used with corn and soybeans. As a first step toward the goal of identifying proper care methods for fabrics contaminated with such pesticides, this research focused on determining whether wash-water temperature, use of detergent, and immediacy of washing after contamination affect removal of fonofos and alachlor from 100% cotton denims used in farm clothing.

MATERIALS

Test Fabrics

Two denim fabrics, a 6-oz shirting weight and a 14-oz pant weight, were obtained from a manufacturer. The fabrics were 2/1 twill in 100% cotton. Except for the denim-blue color of the warp yarns, the fabrics had no finish that might cause interaction between the finish and laundering variables, and potential interference in the extraction of pesticide residues.

Pesticides

A soil insecticide, fonofos (O-ethyl S-phenyl ethylphosphonodithioate), and a herbicide, alachlor (2-chloro-2',6'-diethyl-N-(methoxymethyl)acetanilide), were the two chemicals used to contaminate the test fabrics in emulsifiable-concentrate formulations (four pounds per gallon). Fonofos is widely used for corn and alachlor for corn and soybeans, two major crops in Iowa. The pesticides were used at their original concentrations to simulate accidental spills during handling.

EXPERIMENTAL PROCEDURES

Experimental Design

Wash-water temperature at three levels (60°C, 49°C, 40°C), use of detergent at two levels (with detergent, without detergent), and immediacy of laundering after contamination at two levels (immediate wash, 24-hr delayed wash) were the three independent laundering variables. The dependent variable was the residue amount remaining in the washed specimens. There were 12 cells (3 x 2 x 2) for each of the two pesticide types and the two fabric weights, totaling 48 cells (12 x 4). Five replications, i.e., five fabric swatches as test specimens, were made for each cell, totaling 240 observations.

Preparation and Contamination of Test Specimens

To remove any extraneous matter, the fabrics were washed and dried once without detergent in an automatic home washer and dryer using cycles recommended for the fabric type. Test fabrics were cut into 8 x 8 cm swatches along and perpendicular to the true-bias directions to minimize raveling of yarns during washing.

A one-tier rack of wooden dowels completely wrapped with aluminum foil was set up inside a hood. Fabric specimens were spread out flat on the rack and contaminated by injecting a known amount (0.5 ml) of pesticide using a precision pipette. The

contaminated fabric specimens were either washed immediately or air-dried 24 hours on the rack and then washed.

Laundering and Drying

A modified AATCC Test Method 61-1975 (AATCC, 1979) was used. Two cells were washed at the same time, one with detergent and the other without detergent, at each of the three temperature levels and at each of the two immediacy levels of washing. A contaminated specimen was placed in a metal chamber of an Atlas Launder-Ometer with 150 ml distilled water and 30 steel balls. At the specified temperature and with or without 0.5 g detergent (commercial, phosphate-built), the test specimens were washed for ten minutes. The wash solution was drained and two rinses (5 and 3 min) followed, each in 150 ml cold distilled water. The washed specimens were air dried on the rack for 24 hours. Emptied metal chambers and the neoprene gaskets were decontaminated by successive treatments with 100 ml acetone for ten, five, and three minutes each and dried for subsequent use.

Extraction and GC Analysis

Following the 24-hr air drying after washing, each specimen was placed in a 250-ml Erlenmeyer flask with 100 ml benzene which acted as a solvent to extract pesticide residues and sealed with a screw cap. The flasks were stored in a refrigerator until they were analyzed for residue amount.

Pesticide residue analyses were performed using a Varian 3700 Research Gas Chromatograph equipped with Thermionic Specific Detector. A glass column (1.83 m x 3 mm i.d.) packed with 3% OV-17 on 100/200 Gas Chrom Q utilizing nitrogen as carrier gas at 30 ml/min was used for both fonofos and alachlor. The column temperature was set at 200°C for fonofos and 210°C for alachlor with 300°C injector temperature and 330°C detector temperature. Hydrogen pressure was 25.7 psi with 4.5-ml/min flow and 175-ml/min air flow.

A one micro-liter volume of the extract solution was injected to the column and the peak was recorded. Five replications were made for each specimen. Before and after the five replicated injections, a standard solution (0.5 ml of pesticide in 100 ml benzene without fabric specimen) was injected and average of the two peaks was used as standards. Pesticide residue amounts in percentage were calculated as the ratio of the peak height of the extract solution to the average peak height of the standard solution.

RESULTS AND DISCUSSION

The remaining residue amounts after laundering ranged from 41.9% to 80.7% in fonofos and from 2.2% to 46.9% in alachlor (Table 1). Toxicity level of the residues needs further study.

Effect of Pesticide Type and Fabric Weight

Analysis of variance (ANOVA) was performed with all 240 observations across all pesticide types, fabric weights, and

TABLE 1

% RESIDUE AMOUNT AFTER LAUNDERING[a]

Temperature	With-detergent Wash				Without-detergent Wash			
	6-oz fab		14-oz fab		6-oz fab		14-oz fab	
	Immed wash	Delay wash	Immed wash	Delay wash	Immed wash	Delay wash	Immed wash	Delay wash
Fonofos								
Hot	51.8	64.2	66.3	75.5	57.6	75.8	68.4	75.6
Warm	49.4	63.0	74.0	78.7	65.2	67.5	79.2	80.7
Cool	41.9	69.7	74.7	78.7	56.7	72.8	80.4	76.7
Alachlor								
Hot	2.2	12.6	10.3	25.0	10.2	23.2	30.5	32.5
Warm	2.2	10.5	17.9	31.6	6.9	18.6	20.8	39.3
Cool	3.1	13.2	22.4	46.9	7.9	17.0	28.7	46.0

[a] Mean of five replications

laundering variables to determine the effects of pesticide types and fabric weights. Ease of residue removal differed significantly by chemical type and fabric weight (Table 2): fonofos-contaminated fabrics retained more residues and, within the chemical type, heavier-weight fabrics retained more residues than lighter-weight fabrics (a significance level of 0.01 or beyond is implied when a result is discussed herein as being significant). The thickness and weight of the heavier fabric may allow deeper penetration of the pesticide into the fibers as well as into the fabric structure by a wicking process, making the chemical more difficult to remove.

TABLE 2

EFFECT OF PESTICIDE TYPE AND FABRIC WEIGHT

Source of Variation	df	$\underline{F}$ Value
Pesticide type (P)	1	21340.5*
Fabric weight (W)	1	2487.4*
P x W	1	40.8*

*Significant at or beyond 0.01

The significance of chemical type suggested that each pesticide type should be examined separately in determining efficient laundering methods to remove it. Although lighter-weight fabrics showed lower residue retention, we believe it is premature to recommend them for pesticide-protective clothing because there are other potential problems than the care methods, such as the

transfer of pesticide to the skin. Further study is recommended in this aspect.

Effect of Laundering Variables

Four separate ANOVA's were performed with data on each of the two chemicals and fabric weights to determine the significance of laundering variables on the efficacy of residue removal. Figure 1 summarizes results of the statistical analyses.

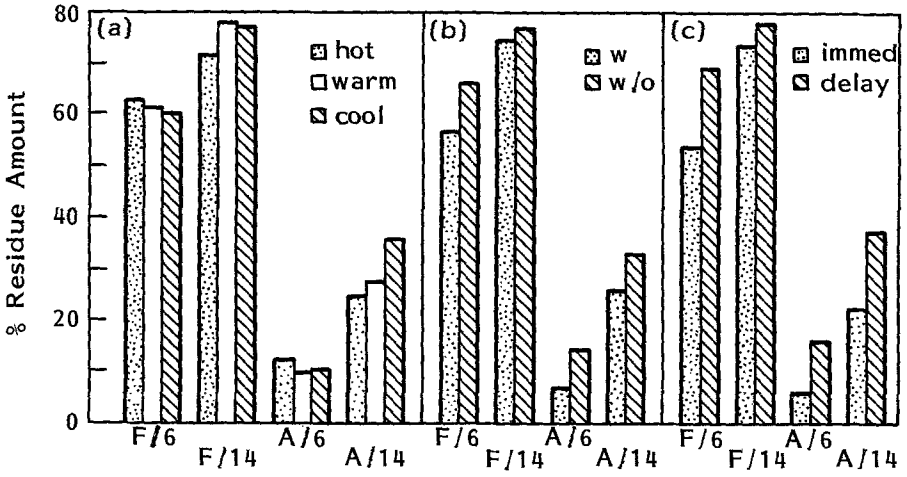

Figure 1. Effect of (a) Wash-Water Temperature, (b) Detergent, and (c) Immediacy of Washing on Residue Removal

Temperature Effect. Residue amounts in fonofos-contaminated 14-oz fabric (F/14), alachlor-contaminated 6-oz fabric (A/6) and 14-oz fabric (A/14) differed significantly by wash-water temperature. However, residue amounts in fonofos-contaminated 6-oz fabric (F/6) were not significantly affected by wash-water temperature.

Figure 1-a and Table 1 show that, for both fonofos and alachlor, the 14-oz fabrics retained more residues than the 6-oz fabrics at all three temperature levels. Also, for both 6-oz and 14-oz fabrics, fonofos residues were much larger than alachlor residues, i.e., alachlor was more readily removed than fonofos. Hot wash showed the smallest residue amounts in F/14 and A/14 fabrics, whereas F/6 and A/6 fabrics retained the largest residue amounts by hot wash although differences in residue amount due to wash-water temperature were small in the lighter-weight fabrics. This suggested that wash-water temperature did not establish a distinctive pattern in efficacy of residue removal: hot wash was more effective in removing residues from the heavier-weight fabrics, whereas for lighter-weight fabrics either warm wash was more effective (for A/6) or wash-water temperature was not a significant factor (for F/6).

Detergent Effect. Detergent effect was significant for all four pesticide/fabric combinations. Figure 1-b and Table 1 show that residue amounts for the with-detergent wash were lower than those for the without-detergent wash. Therefore, use of detergent is recommended in washing fonofos or alachlor-contaminated clothing of 100% cotton denim. However, the amount of residue removal that could be attributed to the use of detergent was smaller than the amount removed by water alone (Table 1). This is consistent with the finding by EASLEY et al. (1981) that pre-rinse plus detergent wash provides more effective removal of methyl parathion than detergent wash without pre-rinse.

Effect of Immediacy of Washing. Figure 1-c and Table 1 show lower mean residue amounts for immediate washing than for 24-hr delayed washing. The significant and large F values (373.0, 28.3, 958.5, 431.7 for F/6, F/14, A/6, A/14 fabrics respectively with df=1,48) for immediacy of washing indicated that immediate washing resulted in significantly greater residue removal. Consequently, immediate washing is recommended after contamination.

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