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To cite this article: Mark M. Methner & Richard A. Fenske (1994) Pesticide Exposure during Greenhouse Applications, Part II. Chemical Permeation Through Protective Clothing in Contact with Treated Foliage, Applied Occupational and Environmental Hygiene, 9:8, 567-574, DOI: [10.1080/1047322X.1994.10388372](https://doi.org/10.1080/1047322X.1994.10388372)

To link to this article: <https://doi.org/10.1080/1047322X.1994.10388372>



Published online: 24 Feb 2011.



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Pesticide Exposure During Greenhouse Applications, Part II. Chemical Permeation Through Protective Clothing in Contact with Treated Foliage

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Protective clothing performance during greenhouse high pressure handspray applications was evaluated with particular reference to the hazard of contact with wet or treated foliage. A fluorescent compound was added to the applicator's spray tank prior to work and served as a surrogate for the pesticides being sprayed. Video-imaging analysis was conducted to determine deposition patterns of the fluorescent tracer on skin, and a modified patch technique was employed outside and inside the protective garment. Four garments constructed of nonwoven, chemical-resistant fabric were tested in an initial study (Tyvek™, Saranex 23-P Tyvek™, Comfortgard™ II, Kleenguard™). All garments exhibited chemical breakthrough after a 1-hour application period. Garments with special treatments to enhance chemical resistance exhibited relatively low levels of breakthrough, whereas garments without such treatment allowed substantial breakthrough. These results prompted an additional study aimed at determining the breakthrough time for the untreated garments (Tyvek, Kleenguard). Breakthrough for both garments occurred between 5 and 15 minutes following the start of application. This study also indicated that results from patch sampling can be misleading if care is not taken in the specific placement of the patches on subjects. It was concluded that none of the garments can be considered chemical resistant under the use conditions observed. Contact with treated foliage represents a special hazard during greenhouse applications, and many chemical protective clothing products in current use are inadequate for worker protection. These products should be redesigned and field-tested to ensure that greenhouse workers do not contact pesticides by this exposure pathway. Methner, M.M.; Fenske, R.A. Pesticide Exposure During Greenhouse Applications, Part II. Chemical Permeation Through Protective Clothing in Contact with Treated Foliage. *Appl. Occup. Environ. Hyg.* 9(8):567-574; 1994.

Introduction

Dermal exposure is considered to be the primary route of exposure for nonvolatile or semivolatile pesticides in agriculture, and can constitute a significant occupational health hazard. Recognition of this hazard has prompted the use of closed systems and chemical protective clothing (CPC) to minimize chemical contact with the skin. While industrial hygienists generally consider personal protective equipment to be a control strategy of last resort,⁽¹⁾ the use of CPC (e.g., gloves, coveralls), as well as goggles and face shields, has become commonplace in the agricultural workplace.⁽²⁾ Indeed, the U.S. Environmental Protection Agency (U.S. EPA) employs CPC as a primary strategy for reducing pesticide exposure during mixing and application, and has issued labels for many commercial pesticide formulations which require specific CPC regimes during product handling.^(3,4)

Permeation, a process by which chemicals move through a material on a molecular level, can occur when protective garments come into contact with workplace compounds.⁽⁵⁾ Chemical permeation evaluation of CPC used in agriculture has been conducted primarily in laboratory settings,⁽⁶⁻⁹⁾ and current testing standards are laboratory based.⁽¹⁰⁾ Only recently have the performances of CPC garments constructed from nonwoven fabrics been tested under field-use conditions,⁽¹¹⁻¹⁶⁾ although such testing procedures have been recommended by the National Institute of Occupational Safety and Health.⁽¹⁷⁾ Two recent studies have focused on protective clothing use during greenhouse handspray applications, but exposure pathways were not examined systematically.^(18,19)

The work reported here was designed to determine the performance of CPC under field-use conditions with special reference to contact with wet or treated foliage during

handspray applications, and to examine the applicability of current dermal exposure measurement techniques in evaluating this hazard.

Methods

Study Design

The initial study examined the barrier effectiveness of four types of protective garments. Workers were asked to conduct normal applications while wearing a protective garment. Only three or four applications were conducted for each garment due to limitations of greenhouse space and subjects. An attempt was made to control basic study parameters to achieve similar exposure potential or challenges across garment types: applicators used the same spray equipment, completed the same number of work cycles, and applied the same amount of fluorescent tracer; bench height, aisle width, and application pressure were constant. The major uncontrolled variables were time worked and extent of foliage contact.

A second study was designed to determine the breakthrough times of two protective garments which exhibited substantial chemical breakthrough in the initial study. A preliminary study was conducted with each garment worn by a single worker while conducting handspray applications for 30 minutes. Subsequent studies involved three workers for each study garment handspraying for 5 and 15 minutes. Additionally, the patch technique was compared with a quasi-whole-body technique to determine the anatomical distribution of leg exposure during contact with wet foliage.

Field Conditions

The first study was conducted at a commercial greenhouse facility in the Tampa Bay region of Florida in 1989. Three or four workers were asked to conduct normal handspray applications on mature poinsettias or chrysanthemums which were densely packed on benches inside a ventilated greenhouse. Foliage contact height began 46 cm above the floor and continued upward to a height of 84 cm. Aisles between benches were 60 cm wide, and foliage extended approximately 18 cm from the edge of each bench into the aisle, leaving an obstructed pathway of only about 24 cm, and making foliar contact with legs unavoidable. The greenhouse ventilation system remained on for the duration of each application and provided unidirectional air flow with a mean air velocity of approximately 5 m/s. Application times ranged from 58 to 95 minutes. Each worker applied one tank, containing 125 gal of water and 75 g of the fluorescent whitening agent, 4-methyl-7-diethylaminocoumarin (Calcofluor RWP; BASF Corp.; CAS No. 91-44-1), dissolved in 0.25 L of natural oil spray adjuvant (Stoller Inc). One control application was conducted for each garment, that is, subjects conducted identical spraying procedures with water only.

The second study was conducted in a Criterion quonset-hut style greenhouse located on a research farm of the New

Jersey Agricultural Experiment Station (NJAES) in 1991. Physical parameters such as aisle width, foliage contact height, and foliage extension were designed to parallel those of the initial study. The ventilation system operated continuously during each application and provided unidirectional airflow of approximately 2 m/s. The spray rig consisted of a tank, 3-hp gas engine, FMC Bean pump (model 61), and 15-m detachable hose attached to a 1-m spray wand assembly equipped with an 80° flat fan single nozzle (Bete Fog Nozzle Inc). An application pressure of 284 kPa (40 psi) was maintained throughout the study. Each tank consisted of 30 gal of water and 30 g of the fluorescent whitening agent, 2,2'-(2,5-thiophenediyl)bis(5-tertbutylbenzoxazole) (Uvitex OB; Ciba-Geigy Corp.; CAS No. 7126-64-5), dissolved in 0.25 L of natural oil.

Chemical Protective Clothing Garments

Four CPC garments were tested in the initial study. Descriptions of the first three were provided by manufacturers in a commercial catalog.⁽²⁰⁾ The description of the Comfort-Gard™ II was taken from the manufacturer's technical data guide.⁽²¹⁾ The garments were as follows:

- Tyvek™ coverall (DuPont Corp): constructed of spun-bonded olefin fibers with serged seams; tear resistant and repels water;
- Saranex 23-P film on Tyvek™ pants (DuPont Corp): constructed with bound seams which prevent chemical seepage and a film which increases water repellency;
- Comfort-Gard II (Durafab, Inc): constructed of a shell, breathable barrier coating, and scrim; barrier to most inorganic and organic liquid challenges;
- Kleenguard™ liquid protection coverall (Kimberly-Clark): composed of 100 percent nonwoven polypropylene; breathable, lightweight, and protects against oils, greases, resins, and water-based liquids.

The Saranex Tyvek and Comfort-Gard will be referred to hereafter as "treated" garments (i.e., a film or coating has been applied to the fabric to increase barrier properties), while Standard Tyvek and Kleenguard will be referred to as "untreated" garments. For the first three types, all garments were new and standard application procedures were adhered to throughout the study. In the case of the Kleenguard garments, however, it was not possible to control two critical factors. First, the garments were in regular use at the study facility and some had been washed prior to use in the study. Second, workers used these garments in houses with a wide variety of plant types; in particular, foliage overhang was virtually absent in some houses, while in others it was similar to that found in the houses where the other garments were tested.

Sampling and Analysis

The video-imaging technique for assessing exposure (VITAE system) was developed to quantify fluorescent tracer deposits on skin under long-wave ultraviolet illumination.⁽²²⁾ The second generation video-imaging system

employed in this study, described in detail elsewhere,⁽²³⁾ was operated with a custom software package and consisted of the following equipment: microcomputer (Compaq 386/20e), digital imaging analysis board (DT2851; Data Translation, Inc.), television camera (4810 monochrome CCD; Cohu, Inc.), zoom lens (Fujinon TV zoom lens; Fuji Optical Co.), television monitor (PVM-1342Q; Sony Corp), and tape backup system (Mountain Filesafe 7060; Mountain Computer, Inc.).

Workers were provided with black athletic shorts and a T-shirt, and entered a darkened mobile laboratory for collection of preexposure video images of the thighs. A corresponding set of images was collected immediately following exposure. Images were adjusted for system noise, changes in illumination between the preexposure and postexposure images, background brightness, and anthropometric features prior to quantification. Fluorescent tracer deposition on skin was quantified by means of a standard curve. The standard curve was generated by spotting a range of known amounts of tracer on human skin and collecting video images of these spotted skin surfaces. The limit of detection, defined as the lowest quantifiable standard, was 35 ng/cm² of exposed skin surface.

Two 10 × 10-cm polyethylene-backed alpha-cellulose filter paper patches were attached at the front of the thighs on the shorts, just above the hemline of each leg. Two additional patches were attached to the outside of the garment just above the inside patch locations, with care taken to avoid overlap. In the first study patch positioning was conducted according to standard procedures, and did not take into account the height of the foliar contact zone, whereas in the second study patches were located at positions on the legs so that direct alignment with the foliar contact area was maintained regardless of worker height. A quasi-whole-body or "vertical strip" method was employed in an ancillary study with two workers of differing heights (173 and 188 cm). Four vertical strips of 10-cm-wide alpha-cellulose were attached to the outside of the upper and lower leg regions of a coverall. Each worker then sprayed 39 L (10 gal) of water containing 10 g of Uvitex OB dissolved in 0.25 L of natural oil.

Patches were removed by staff wearing surgical gloves, covered with a blank patch, wrapped in aluminum foil, labeled, and stored in a freezer (0°C) pending transportation to the laboratory. They were later thawed to room temperature for 1 hour, cut such that a 5 × 5-cm center square remained, transferred to a glass jar, and extracted with 25 ml of pesticide-grade toluene for 30 minutes on a high speed (100 cpm) shaker table (Eberbach Co). Similar procedures were employed for the vertical strip samples, that is, the strips were cut into small segments and extracted. Extracts were analyzed by a Turner 430 spectrofluorometer (Sequoia-Turner Corp) at the following settings: Calcofluor RWP, excitation = 370 nm, emission = 410 nm, bandwidth = 15 nm; Uvitex OB, excitation = 376 nm, emission = 430 nm, bandwidth = 15 nm. Quantitation was achieved by a standard curve using external standards. The

limit of detection was 0.14 ng/cm² for Calcofluor RWP and 5.6 ng/cm² for Uvitex OB.

Quality Control Procedures

The performance of the video-imaging system was monitored continuously in the field. Images of a standard target were acquired prior to and immediately following each imaging session for each worker. The percent differences across preexposure sessions, postexposure sessions, and worker evaluation sessions were all less than 5 percent, indicating stable conditions throughout data collection. Extraction efficiencies for the dermal monitors were determined by fortifying alpha-cellulose patches with the two compounds at two levels encompassing the range anticipated in field samples. The mean recovery for Calcofluor RWP from the patches was 99.9 ± 3.1 percent. Uvitex OB was very similar, with a recovery of 97.8 ± 2.1 percent. Two patch field blanks were collected for each worker by placing the patch at the intended patch locations, removing, handling, and analyzing them in a manner identical to the other patches. All field blanks were below the detectable limit of the instrument. Samples spiked in the field showed no evidence of degradation.

Results

Dermal exposure measurements obtained with the video-imaging technique are presented in Table I. Garment challenge was estimated by multiplying the outer patch values for each worker by the surface area of the front and outer surface of the thighs measured by the video-imaging system. Skin deposition rates of fluorescent tracer beneath garments ranged from 2 to 939 µg/h (425fold). Percent permeation values within each garment type were highly variable. In the case of greatest skin deposition (Standard Tyvek), percent permeation exceeded 100 percent, indicating that the patch-based challenge estimate was artificially low. The washed and unwashed Kleenguard garments which received very high challenges exhibited similar permeation. The highest median percent permeation was found with the washed Kleenguard (39%), followed by Standard Tyvek (16%) and unwashed Kleenguard (6%). The Saranex Tyvek and Comfort-Gard exhibited breakthrough in all cases, but had an overall mean permeation value of <1 percent.

Left and right thigh patches from each subject were pooled to calculate the deposition values presented in Table II. Garment challenges (outer patch deposition) ranged from 25 to 9500 ng/cm²/h (3800fold). This high variability was probably due to differences in foliage overhang, work practices, and patch location relative to the foliar contact zone. Challenges to the Kleenguard garment exhibited the greatest variability, since applications were conducted on plants in various growth stages. Challenges for the other three garments ranged from 50 to 6200 ng/cm²/h (124fold).

Inner patch values ranged from <0.14 to 59 ng/cm²/h for new garments. A very high deposition value (2583 ng/cm²/

TABLE I. Video-Imaging Analysis of Fluorescent Tracer Deposition on Skin

Garment Type	Worker	Garment Condition	Estimated Challenge ($\mu\text{g}/\text{h}$) ^A	Skin Deposition ($\mu\text{g}/\text{h}$)	Permeation (%) ^B	Mean	Median
Standard Tyvek	1	New	343.0	939.3	274.0	98.1	15.6
	2		3163.0	493.1	15.6		
	3		1528.0	70.9	4.6		
Saranex Tyvek	1	New	4783.0	43.8	0.90	2.3	0.90
	2		75.0	4.5	6.0		
	3		5610.0	6.7	0.12		
Comfort-Gard	1	New	3108.0	17.4	0.56	15.7	0.56
	2		7874.0	2.2	0.03		
	3		62.1	28.8	46.4		
Kleenguard	1	Washed	414.0	2.8	0.68	40.0	39.3
	2		3.1	2.5	80.6		
	3		32.1	11.2	34.9		
	4		72.7	31.8	43.7		
Kleenguard	1	Washed	10,531	377.5	3.6		
Kleenguard	1	New	12,071	672.9	5.6		

^AOuter patch values \times measured surface area.

^B(Skin deposition/estimated challenge) \times 100.

h) was measured for a washed Kleenguard garment which received a high challenge, while a new Kleenguard garment receiving a similar challenge had only 5 ng/cm²/h on the inner patches. Washed Kleenguard garments with lower challenges had inner deposition values similar to those observed for the other test garments. Breakthrough frequency was 100 percent (12 of 12) for Kleenguard garments, washed or unwashed, while breakthrough frequency for the other garments was either 67 percent (4 of 6, Standard Tyvek) or 50 percent (3 of 6, Saranex Tyvek and Comfort-Gard). Per-

cent permeation for each garment was calculated by dividing the inner patch rate by the challenge rate and multiplying by 100. Results were highly variable, with no correspondence between challenge and inner patch deposition. However, the mean and median percent permeation values exhibited a similar pattern: the two untreated garments (Standard Tyvek and washed Kleenguard) had higher values than the two treated garments (Saranex Tyvek and Comfort-Gard). Thus, the patterns of breakthrough and skin deposition observed with video-imaging analysis were

TABLE II. Patch Deposition Rates Outside and Inside Protective Garments

Garment Type	Worker	Garment Condition	Outer Patch Deposition (ng/cm ² /h)	Inner Patch Deposition (ng/cm ² /h)	Breakthrough Frequency ^A	Permeation (%) ^B	Mean (%)	Median (%)
Standard Tyvek	1	New	272	58.7	4/6	21.8	7.98	2.14
	2		2502	53.6		2.1		
	3		1209	<0.14 ^C		0.01		
Saranex Tyvek	1	New	3784	4.4	3/6	0.12	0.21	0.22
	2		59	<0.14 ^C		0.29		
	3		4438	9.9		0.22		
Comfort-Gard	1	New	2459	27.3	3/6	1.11	0.58	0.60
	2		6629	0.76		0.01		
	3		49	0.30		0.60		
Kleenguard	1	Washed	328	3.24	8/8	1.00	6.10	2.86
	2		2.5	0.44		17.7		
	3		25	0.85		3.35		
	4		58	1.36		2.37		
Kleenguard	1	Washed	8332	2583	2/2	31.0		
Kleenguard	1	New	9550	4.84	2/2	0.05		

^ANumber of patches on which measurable residues were detected/total patches; limit of detection = 0.14 ng/cm².

^B(Inner patch rate/outer patch rate) \times 100.

^CInner patch values < limit of detection; limit of detection used for percent penetration calculation.

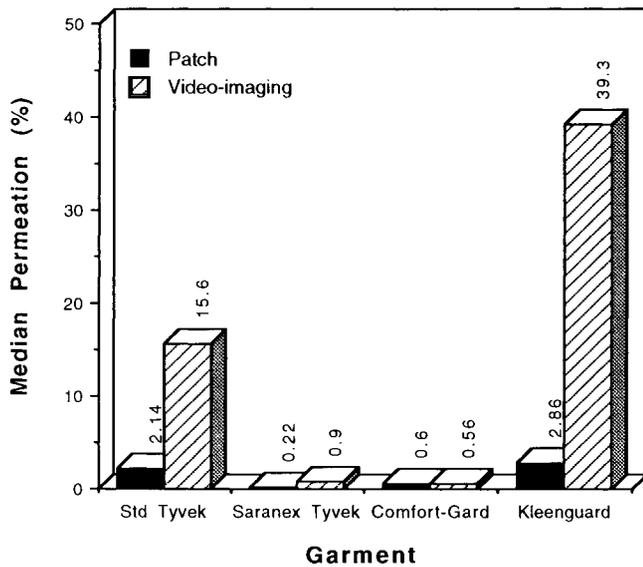


FIGURE 1. Median percent permeation of four chemical protective garments following greenhouse handspray applications on ornamentals: comparison of video-imaging and patch measurements. Untreated garments allowed substantially greater permeation.

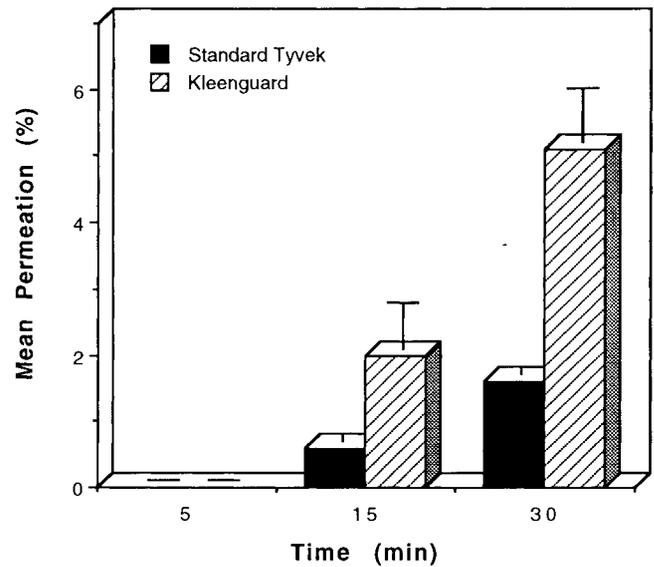


FIGURE 2. Chemical breakthrough of two untreated chemical protective garments during greenhouse handspray applications on ornamentals. No breakthrough was observed after 5 minutes for either garment.

generally confirmed by the patch data, although the magnitude of garment permeation values differed substantially between the two sampling techniques, as indicated in Figure 1.

In the second study mean challenge rates were consistent for both the Standard Tyvek and Kleenguard garments (Table III). The initial 30-minute applications resulted in substantial breakthrough for both garments. The application times were therefore decreased to 15 and 5 minutes with three replicate applications conducted in each case for both garments. Patches beneath the garments had detectable levels of tracer after the 30- and 15-minute application periods, but were below the limit of detection (6 ng/cm²) after the 5-minute application period. Postexposure visual examination of the thighs confirmed that low levels of tracer had penetrated both garments during the 30- and 15-minute application periods, but these levels were deemed too low to quantify with the video-imaging system.

The Kleenguard garment exhibited approximately three times greater chemical breakthrough than the Standard Tyvek, as illustrated in Figure 2. The mean percent permeation for Kleenguard was significantly greater than that of the Standard Tyvek at 15 minutes (Kruskal-Wallis: $p < 0.01$).

The vertical strips employed to approximate whole-body sampling covered about 60 percent of the upper legs for both workers, and covered virtually all of the lower legs of the shorter worker but only about one-half for the taller worker (Table IV). In contrast, traditional patches covered at most about 4 percent of the anatomical regions under study.⁽²⁴⁾ For both applicators the upper legs were more exposed than the lower legs. Visual inspection of work practices and the exterior of the garments indicated that this difference was due to the upper legs being contacted repeatedly by foliage while the lower legs were exposed primarily to foliar runoff.

The tracer deposition rate measured on the upper leg

TABLE III. Breakthrough Times of Untreated Protective Garments During Foliar Contact

Garment	Application Time (minutes)	N	Challenge Rate ($\mu\text{g}/\text{cm}^2\text{h}$)		Inner Patch Rate ($\mu\text{g}/\text{cm}^2\text{h}$)		Percent Penetration ^b	
			Mean	C.V. ^a	Mean	C.V.	Mean	C.V.
Standard Tyvek	30	2	12.4	6	0.19	0	1.6	6
Kleenguard	30	2	10.9	3	0.54	13	5.1	16
Standard Tyvek	15	6	13.3	11	0.08 ^c	27	0.6 ^c	17
Kleenguard	15	6	13.4	14	0.26 ^c	32	2.0 ^c	35
Standard Tyvek	5	6	8.34	29	<0.07	—	—	—
Kleenguard	5	6	7.72	45	<0.07	—	—	—

^aCoefficient of variation = (standard deviation/mean) \times 100.

^b(Mean inner patch rate/mean challenge rate) \times 100.

^cMean inner patch rate and percent penetration for Kleenguard significantly greater than for Standard Tyvek. (Kruskal-Wallis: $p < 0.01$). Challenge rates for two garments not significantly different.

TABLE IV. Effect of Sampling Technique and Worker Height on Estimated Dermal Exposure to the Legs

Leg Region	Worker Height (cm)	Standard Surface Area (cm ²) ^A	Measured Surface Area (cm ²) ^B	Sampling Area ^C (%)		Tracer Deposition Rate (µg/cm ² /h)		Estimated Exposure (mg/h) ^D		
				Patch	Strip	Patch	Strip	Patch	Strip	Patch/Strip
Upper	173	3820	2940	1.8	63.3	301.2	47.8	1150.6	182.9	6.3
	188			1.6	57.4	63.5	56.5	242.9	215.9	1.1
Lower	173	2380	1239	4.2	100.1	4.24	32.0	10.0	75.9	0.13 (7.6) ^E
	188			2.0	47.3	3.29	17.7	7.65	42.4	0.18 (5.5)

^AFrom ref 23; upper legs include hips and buttocks.

^BBased on field measurements and geometric cone model (upper leg) and cylinder model (lower leg); upper legs = top of patella to crotch; lower legs = bottom of patella to ankle.

^CPercent of alpha-cellulose covering measured surface area; patch = two 25.8-cm² pads; strip = four vertical strips of alpha-cellulose per leg region.

^DTracer deposition rate × measured surface area.

^ENumber in parentheses is inverse of ratio.

patches of the shorter worker was substantially greater than that measured on the strips, resulting in a sixfold difference in exposure estimates for the two techniques. For the taller worker, however, estimates were nearly identical. Exposure estimates for the lower legs were lower for the patch technique than for the strips (fivefold to sevenfold) for both workers. The vertical strip method can be used to illustrate the depositional patterns which occur during foliar contact (Figure 3). Minimal amounts of tracer were deposited on the inner and back portions of the legs as compared with the front and outer portions. For the shorter worker the traditional patch location (front-middle) was in the center of the foliar contact zone, and this patch received the greatest exposure of all leg patches. The same patch location, shifted 15 cm higher for the taller worker, received only moderate exposure. Clearly extrapolation of

deposition rates on the front-middle patches to the entire upper leg region led to overestimation of exposure for the shorter worker (the concordance of patch and strip values for the taller worker in this case appears serendipitous), whereas the converse was true for the lower legs of both workers.

Discussion

Two independent dermal exposure methods found that measurable amounts of a fluorescent tracer employed as a surrogate for pesticides were deposited on the skin of workers wearing CPC. These results indicate that the four CPC garments that were tested, and which are currently available for pesticide applicators in agriculture, can allow chemical breakthrough under normal use conditions.

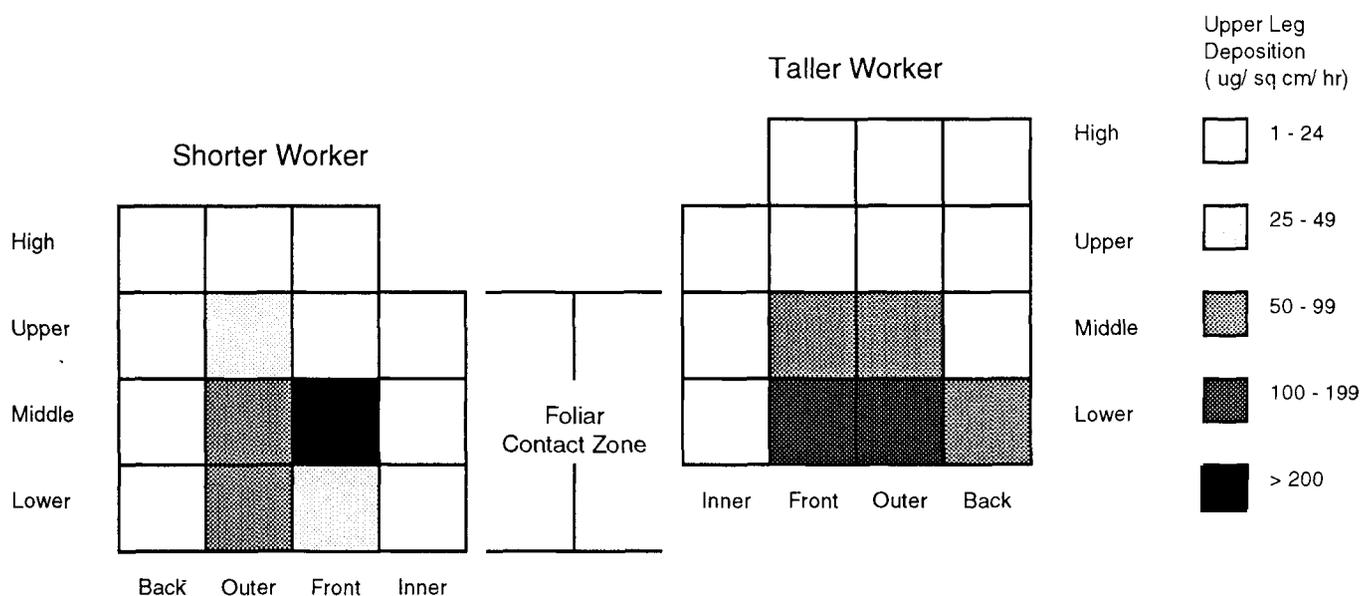


FIGURE 3. Anatomical distribution of fluorescent tracer deposition for theoretical patch locations on the upper legs of two workers of differing heights (173 and 188 cm). Leg patches have been "unwrapped" to allow comparison of different leg portions (back, outer, front, inner). Patch locations are designated vertically as high, upper, middle, lower. The traditional patch location for the upper leg is front-middle. Note that the foliar contact zone differs for the two workers relative to patch locations.

Treated garments appear to provide better protection than untreated, but none of the tested garments can be considered completely chemically resistant under these exposure conditions.

It is very unlikely that skin deposition occurred by routes other than fabric permeation, since all garments had tight-fitting closures. The lack of detectable fluorescence on the skin of control applicators (water spray only) indicated that the dermal exposure patterns observed were the result of the handspray applications conducted during the study. The high variability of skin deposition rates observed both within and across garment types in the first study was due in large part to the use of the traditional patch technique. Results of the second study demonstrated that dermal exposure under these conditions is nonuniform and that specific patch location can affect measured values dramatically. The inherent limitations of the patch technique in this regard have been noted previously.^(25,26)

This study design had several limitations. First, sample sizes were small. In each aspect of the study, however, findings were consistent in regard to chemical breakthrough patterns. Second, results rest exclusively on analysis of a fluorescent compound employed as a surrogate for pesticides. To the extent that tracer exposure is not representative of pesticide exposure, conclusions drawn from these data may not be valid. However, applicator exposure to pesticides appears to be dependent primarily on physical processes rather than chemical properties, indicating the likely validity of surrogate data.^(27,28) Previous studies have demonstrated that the fluorescent compound employed here deposits in proportion to pesticides during spraying,⁽²⁹⁻³¹⁾ and can serve as a surrogate for pesticide deposition beneath protective clothing.⁽³⁰⁾ Use of a fluorescent tracer as a surrogate compound in this study had two advantages: chemical analysis was limited to a single compound, and exposure patterns were visible under long-wave UV lights, introducing a worker training component to the study.

The results of this study are in agreement with those of a study of greenhouse handgun applicators in which breakthrough of CPC was observed.⁽⁸⁾ A recent study of 125 greenhouse applicators concluded that wearing whole-body protective clothing was of value in preventing percutaneous absorption of pesticides,⁽⁹⁾ but this conclusion was based on group cholinesterase values rather than measurements of dermal exposure, and the role of chemical breakthrough due to contact with treated foliage was not discussed. Clearly CPC use does reduce exposure during greenhouse applications, but it cannot be assumed to prevent such exposures completely.

Conclusions

Several conclusions can be drawn from this study: (1) garments normally considered chemical resistant during applications may exhibit breakthrough in a relatively short time due to repeated contact with wet foliage and thus pro-

vide inadequate protection for applicators; (2) field testing under actual greenhouse application conditions is essential for proper evaluation of CPC performance; (3) the anatomical distribution of dermal exposure during greenhouse applications is not uniform, and patch sampling may produce misleading measurements; (4) fluorescent tracers can serve as a useful training tool in the greenhouse environment.

Several strategies are available to prevent or mitigate dermal exposure during greenhouse applications. Greenhouse benches could be redesigned to minimize overhanging foliage, thus eliminating the hazard to the worker. This solution has economic disadvantages, since it would require increasing the size of greenhouses without increasing crop production. Alternatively, bench configurations could be revised to provide the applicator with an exit at the end of each row, thereby reducing contact with previously sprayed plants. If such approaches are not feasible, then CPC will need to serve as the primary control strategy for these workers. In this case it is re-emphasized that garments employed in greenhouses should be truly chemical resistant, and this property should be demonstrated through field testing under realistic conditions. In some cases it may be appropriate to require the use of a double layer of protection (e.g., coverall plus apron), but it must be stressed that this requirement puts an additional burden on an applicator working in what is often a hot and humid environment.

Recommendations

1. Applicator contact with treated foliage in greenhouses should be minimized as much as possible.
2. CPC should be field-tested under realistic conditions prior to use in greenhouse environments.
3. Greater guidance regarding CPC should be provided to users by manufacturers and government agencies.
4. Garments that are designated as disposable should not be washed and reused; garments should not be labeled as washable unless postwash barrier properties have been properly tested.
5. Applicator leg protection should be increased when contact with treated foliage is unavoidable.

Acknowledgments

The authors thank the National Institute of Occupational Safety and Health (grant no. 1 KO1 OH00063) for funding support. A mobile laboratory, provided by the U.S. EPA Office of Research and Development to support related occupational exposure research under cooperative agreement No. CR-814919, was used for the field components of this study. Laboratory work was conducted at the NJAES, and this work was supported in part by NJAES. In addition, this work could not have been completed without the technical support of Shari Birnbaum and the cooperation of all volunteers, including Earl J. Small Growers, Pinellas Park, Florida. Special thanks to the staff of the NJAES Vegetable Re-

search Farm 3 for assistance in greenhouse construction and maintenance.

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