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Residual Air Concentrations of Pesticides in a Commercial Greenhouse

Dawn Tharr, Column Editor

Report by Steven W. Lenhart and Melody M. Kawamoto

Introduction

The National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation (HHE) at two facilities of a large midwestern greenhouse company. The company produces a variety of floriculture and nursery products such as bedding, seasonal and ornamental plants, and foliage under permanent, environmentally controlled greenhouses. Slightly more than half of the company's production greenhouses are glass structures with passive ventilation systems, and the remainder are gutter-connected double-polyethylene structures with mechanical exhaust ventilation systems. The purpose of this report is to describe the activities, findings, and recommendations associated with the air sampling aspects of the HHE. These aspects included area air sampling before, during, and after high-volume spraying and coldfogging applications of diazinon in greenhouse sections with passive ventilation systems, and area air sampling during and after a coldfogging application of chlorpyrifos in a greenhouse section with a mechanical exhaust ventilation system. Diazinon exposure of the pesticide applicator was also estimated by personal breathing-zone (PBZ) air sampling during the spraying application. The persistence of pesticides in the work environment, representing potential for exposure to greenhouse workers, was evaluated by area air sampling for three to four consecutive days after spraying and coldfogging applications. Air sampling at the company facility designated Plant 1 reflected environmental conditions in a greenhouse with a passive ventilation system, and air sampling at the company facility designated Plant 2 reflected conditions in a greenhouse with a mechanical exhaust ventilation system.

Methods

Pesticide application methods and air sampling methods associated with three pesticide applications at two facilities of the greenhouse company are summarized in Table I and described below.

Pesticide Application Methods

Plant 1

Area air sampling for diazinon was conducted in Section 3 and Section 4 of Plant 1 during the work shift just prior to pesticide applications in each section. That evening, one PBZ and four area air samples were collected in Section 3 during a 40-minute application by high-volume spraying of an emulsifiable concentrate (EC) formulation of diazinon (Clean Crop AG500). The hazardous ingredients identified in the material safety data sheet (MSDS) for Clean Crop Diazinon AG500 Insecticide (Platte Chemical Company, Fremont, Nebraska) are 48 percent diazinon and 36 percent xylene. In preparation for spraying, the applicator added 1.4 liters (approximately 3 pints) of Clean Crop AG500 (diazinon EC) to 100 gallons of water contained in one of the two holding tanks of the pesticide pumping equipment. The insecticide was applied at a nozzle pressure of 500 pounds per square inch gauge (psig) to potted golden and marble queen pothos *(Scindapsus aureus)* in plastic baskets on waist-high plant benches, and to English ivy *(Hedera helix)* in plastic baskets hanging from the ceiling and from the outer edges of the benches. Section 3 does not have exhaust fans, but passive ventilation is provided by adjustable windows (vents) in the greenhouse roof. Warning signs in English and Spanish were posted on doors to the section before and during the application. The signs listed the name of the pesticide applied, the time of application, and the time when reentry by unprotected individuals was permitted. During the application, the five air-circulating fans in the section were not in operation, and the roof vents were closed.

After the spraying application and just before leaving the facility for the day, the applicator added 1.4 liters of diazinon EC to 18 liters of water contained in a reservoir on each of two coldfogging machines located in Bays A and B, and in Bays C and D of Section 4. The timers of these devices were set for a four-hour coldfogging application to begin after the applicator left the facility. Warning signs were posted on the doors to Section 4 before and dur-

TABLE I. Pesticide Application Methods and Air Sampling Methods at Two Greenhouse Facilities

Facility	Ventilation Method	Pesticide Applied	Application Method	Air Sampling
Plant 1	Passive	Diazinon EC	Spraying	PBZ*, Area
Plant 1	Passive	Diazinon EC	Fogging	Area
Plant 2	Mechanical	Chlorpyrifos EC	Fogging	Area

*PBZ = personal breathing zone of pesticide applicator.

ing the application. The roof vents were closed and the air-circulating fans were not in operation during the application. Area air samples for diazinon were collected hourly at four locations of Bays A and B during the application.

During the first four consecutive days after the pesticide applications, full-shift area air samples were collected at four locations in Section 3 and at four locations in Section 4. In both sections, the air-circulating fans were continuously operating and the roof vents were occasionally open during the postapplication sampling periods.

Plant 2

Area air samples were also collected at five locations in Plant 2 during and immediately after a 5-hour coldfogging application of an EC formulation of chlorpyrifos. Area air sampling was conducted in Section B-2, where the coldfogging application occurred, and in the two adjacent sections (B-1 and B-3), which were separated from Section B-2 by plastic partitions. All three sections contained potted garden mums that had been set directly on the concrete floors. Before the coldfogging operation, the grower added 0.5 liter (approximately 1 pint) of Dursban® 2E Insecticide to 16 liters of water contained in the reservoir on the model LVH-10 coldfogging device. The hazardous ingredients identified in the MSDS for Dursban 2E Insecticide (DowElanco, Indianapolis, Indiana) are 24.1 percent chlorpyrifos and 75.9 percent other ingredients, which include xylene, 1,2,4-trimethylbenzene, cumene, and methyl chloroform. Plant 2 differs from Plant 1 in that eleven 48-inch propeller-type axial exhaust fans are located along one entire wall of each greenhouse section. The entire wall opposite the fans is vented to provide replacement air. Before and during the monitored application, the doors of Section B-2 were posted with warning signs. The coldfogging device was located on the walkway midway between the wall with exhaust fans and the vented wall; the device's outlet nozzle faced the exhaust fans. During the 5-hour coldfogging application, the exhaust fans were not in operation, the vent was closed, and the three air-circulating fans in the section were in operation. For 2 hours after the application, no fans were in operation, and the vent was closed. After this period, the vent was opened, and one of the exhaust fans was operated for 2.5 hours to remove residual pesticide aerosol. During the first three consecutive days after the application, full-shift area air samples were collected at the same five sampling locations. Ten of the eleven exhaust fans and all three air-circulating fans in Section B-2 were in operation during each postapplication sampling period.

Air Sampling Methods

Air samples were collected for diazinon at Plant 1 and for chlorpyrifos at Plant 2 using SKC® OSHA Versatile Sampler (OVS) sorbent tubes (SKC, Valley View Road, Eighty Four, Pennsylvania), which consist of a quartz filter and XAD-2 sorbent material (catalog number 226-58). During sampling, each OVS sorbent tube was connected by flexible tubing to a personal sampling pump operated at a flow rate of 1 L/min. Each sampling tube was desorbed and analyzed according to NIOSH Method 5600[9] (draft) with modifications.

Organophosphate Insecticides

A variety of organophosphate chemicals are commonly used as insecticides because they are biodegradable as well as effective. Organophosphate chemicals, however, can cause adverse health effects in exposed humans through the inhibition of cholinesterase (ChE) enzymes. Because of the potential for adverse health effects in workers, occupational exposure limits have been established for some organophosphate insecticides, including diazinon and chlorpyrifos.

Diazinon

Diazinon (CAS number 333-41-5) is an organophosphate insecticide used to control soil insects and pests of fruits, vegetables, tobacco, forage, field crops, range, pasture, grasslands, and ornamental plants. Diazinon is also used for seed treatment and to control grubs, nematodes in turf, cockroaches, flies, and other household insects.[2] Because its half-life in soil is 30 days, it is considered a moderately persistent insecticide.[3] The NIOSH recommended exposure limit (REL) and the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) for diazinon are 100 $\mu g/m^3$ [8-hour time-weighted average (TWA)].[4,5] The TLV has a skin notation, which indicates that a substance can be absorbed through the skin in sufficient quantities to cause toxicity to other parts of the body. OSHA did not have a permissible exposure limit (PEL) for diazinon prior to the 1989 Air Contaminants Standard,[6] which was vacated by the 11th Circuit Court of Appeals in 1992. Therefore, there is no currently enforceable federal standard for this pesticide. Some states operating their own OSHA-approved job safety and health compliance programs, however, may enforce the 100 $\mu g/m^3$ limit.[6] Depending upon the formulation, diazinon-containing insecticides are classified under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) as category II, III, or IV.[2] FIFRA categories are equivalent to toxicity ratings ranging from extremely toxic (category I) to practically nontoxic (category IV).[7]

Chlorpyrifos

Chlorpyrifos (CAS number 2921-88-2) (Dursban) is also an organophosphate insecticide. It is used to control fire ants, ornamental plant insects, stored product insects, and turf and wood destroying insects.[2] Because its half-life in soil is 30 days, it is considered a moderately persistent insecticide.[3] The NIOSH REL and ACGIH TLV for chlorpyrifos are 200 $\mu g/m^3$ (8-hour TWA), and the TLV has a skin notation.[4,5] As with diazinon, OSHA did not have a PEL for chlorpyrifos prior to the 1989 Air Contaminants Standard.[6] Therefore, there is no currently enforceable federal standard for this pesticide either. Some states operating their own OSHA-approved job safety and health compliance programs, however, may enforce the 200 $\mu g/m^3$ limit.[6] Chlorpyrifos-containing insecticides are classified as FIFRA category II pesticides.[2]

TABLE II. Air Concentrations of Diazinon During a Spraying Application of Diazinon EC in Section 3 of Plant 1 on a Friday Evening

Sampling Location	Sampling Duration (minutes)	Diazinon Concentration ($\mu g/m^3$)	
		Actual	8-Hour TWA
On applicator	53	226	25.0
Table C-21	38	239	18.9
Table C-7	37	297	22.9
Table A-6	38	ND*	ND
Near entrance	38	ND	ND

*ND = none detected.

Results

Plant 1

The results of area air sampling for diazinon conducted during the work shift just prior to the pesticide applications in Sections 3 and 4 of Plant 1 were either nondetectable or trace concentrations.

The results of a PBZ sample and four area air samples collected during the spraying application of diazinon EC in Section 3 are shown in Table II. Diazinon concentrations measured during the application period and 8-hour TWA concentrations are shown. Residual air concentrations of diazinon measured in Section 3 over the weekend and during the first two work shifts of the next work week are shown in Table III. Residual levels of diazinon remained in the air of this section throughout these postapplication days. The results of 16 area air samples collected hourly at four locations during the 4-hour coldfogging application of diazinon EC in Section 4 are shown in Table IV. By comparison, diazinon concentrations measured during the coldfogging application in Section 4 (Table IV) far exceed the levels measured during the spraying application of the same pesticide in Section 3 (Table II). Residual air

TABLE III. Residual Air Concentrations of Diazinon in Section 3 of Plant 1 for Four Days After a Spraying Application

Sampling Location	8-Hour TWA Diazinon Concentration ($\mu g/m^3$)			
	Saturday	Sunday	Monday	Tuesday
Table C-21	52	21	12	12
Table C-7	45	30	17	ND*
Table A-6	6.1	3.0	2.4	2.5
Near entrance	6.0	4.2	3.1	2.9

*ND = none detected.

TABLE IV. Area Air Concentrations of Diazinon During a Coldfogging Application of Diazinon EC in Section 4 of Plant 1 on a Friday Night

Sampling Location	Sampling Duration (minutes)	Diazinon Concentration* ($\mu g/m^3$)
Table B-20	234	3030 (1.2)
Table B-12	233	2100 (1.2)
Table A-21	237	780 (1.4)
Table A-12	239	730 (1.3)

*Diazinon concentration = Geometric mean (standard deviation) of four 1-hour area air samples.

TABLE V. Residual Air Concentrations of Diazinon in Section 4 of Plant 1 for Four Days After a Coldfogging Application

	8-Hour TWA Diazinon Concentration ($\mu g/m^3$)			
Sampling Location	**Saturday**	**Sunday**	**Monday**	**Tuesday**
Table B-20	250	67	59	40
Table B-12	230	60	51	38
Table A-21	81	27	30	23
Table A-12	70	27	20	19

concentrations of diazinon measured over the weekend and during the first two work shifts of the next week are shown in Table V for Section 4. Full-shift area air concentrations measured at two locations in Section 4 on the day after the coldfogging application exceeded the 100 $\mu g/m^3$ occupational exposure limit of diazinon, and substantial residual levels persisted in the air of this section throughout these postapplication days.

Plant 2

The results of area air sampling for chlorpyrifos at Plant 2 are presented in Tables VI and VII. The sampling results presented in Table VI represent 1) the coldfogging application period [2200–0300], 2) the period immediately after the coldfogging period when the section was completely closed and none of the exhaust fans or air-circulating fans was in operation [0300–0500], and 3) the period when mechanical ventilation was in operation [0500–0730]. According to a representative of the greenhouse company, the one exhaust fan that operated during the third sampling period produced a flow rate of 20,700 ft^3/min. Therefore, since Section B-2 had a cross-sectional area of 1,440 ft^2, an average air velocity of 14.4 ft/min was produced by this fan. Full-shift area air concentrations of residual chlorpyrifos measured at three locations of Section B-2 and at single locations in each of Sections B-1 and B-3 are presented in Table VII. The concentrations presented in Table VII are all well below the 200 $\mu g/m^3$ occupational exposure limit of chlorpyrifos.

TABLE VI. Area Air Concentrations of Chlorpyrifos During and Shortly After a Coldfogging Application of Chlorpyrifos EC in Section B-2 of Plant 2 on a Friday Night

Sampling Location	Sampling Period	Sampling Duration (minutes)	Chlorpyrifos Concentration ($\mu g/m^3$)
Walkway	Fogging	334	988
	Closed	113	133
	One fan	139	49
Fan side	Fogging	333	1620
	Closed	112	107
	One fan	133	75
Vent side	Fogging	329	638
	Closed	111	99
	One fan	129	25
Section B-1	Fogging	320	66
	Closed	110	14
	One fan	127	15
Section B-3	Fogging	338	189
	Closed	115	40
	One fan	124	2

TABLE VII. Residual Air Concentrations of Chlorpyrifos in Section B-2 of Plant 2 for Three Days After a Coldfogging Application

	8-Hour TWA Chlorpyrifos Concentration ($\mu g/m^3$)		
Sampling Location	**Saturday**	**Sunday**	**Monday**
Walkway	6.7	1.1	0.5
Fan side	7.9	1.3	0.6
Vent side	2.7	0.5	ND*
Section B-1	1.0	ND	ND
Section B-3	0.3	0.1	ND

*ND = none detected.

Discussion

On October 20, 1992, the Environmental Protection Agency (EPA) amended 40 CFR 156.10–Labeling Requirements for Pesticides and Devices to incorporate by reference the Final Rule for Part 170–Worker Protection Standard.[8] The sale and distribution of pesticide products with amended labeling under Part 156 by pesticide registrants was permitted after April 21, 1993. Only pesticide products with amended labeling are permitted to be distributed or sold by any registrant after April 21, 1994. "As pesticide products with amended labeling are used, EPA will begin to enforce the provisions of Part 170 that are related to the new specific requirements on pesticide product labeling for restricted-entry intervals, personal protective equipment, and notification about treated areas."[8]

The EPA Worker Protection Standard (Part 170) was "designed to reduce the risks of illness and injury resulting from occupational exposure to pesticides used in the production of agricultural plants on farms or in nurseries, greenhouses, and forests and also from the accidental exposure of workers and other persons to such pesticides."[8] The standard defines restricted-entry intervals for greenhouses during which period an employer shall not allow or direct any person, other than an appropriately

trained and equipped handler, to enter or to remain in a pesticide-treated area. According to section 170.110(c), when a pesticide is applied 1) from a height of greater than 12 inches from the planting medium, 2) as a fine spray, or 3) using a spray pressure greater than 40 psi, workers are prohibited in the treated area plus 25 feet in all directions in the enclosed area only until the application is completed. The position of EPA is that "after application is completed, the sprays will settle out of the air and no longer pose an exposure hazard to adjacent workers."[8]

During a previous spraying application, the applicator wore an unhooded disposable protective suit, industrial-grade latex gloves, a NIOSH-approved half-mask respirator with pesticide cartridges, and rubber boots. The respirator appeared to be too small for its wearer's face, and spaces were observed between the mask and both sides of the applicator's nose. The applicator reported that he had not been fit tested prior to receiving the respirator, and that he had not changed the cartridges "in some time." Because of the obvious inadequate fit of the respirator, the half-mask respirator probably provided the applicator with essentially no inhalation protection.

During the closing meeting of the initial site visit, NIOSH investigators recommended that a complete respirator program for respirator users at all of the company's facilities be implemented in accordance with OSHA regulations and NIOSH recommendations. Replacement of respirator cartridges in accordance with the NIOSH guidance, which states "because of the limited useful service time of canisters and cartridges, they should be replaced daily or after each use, or even more often if the wearer detects odor, taste, or irritation," was recommended.[9] Wearing a hooded disposable protective suit during pesticide spraying was also recommended. The company implemented these recommendations prior to the next NIOSH site visit. During subsequent spraying applications, the applicator wore a hooded disposable protective suit, industrial-grade latex gloves, a NIOSH-approved full-facepiece respirator with pesticide cartridges, and rubber boots. Because of the apparent adequate fit of the full-facepiece respirator, the applicator probably received less inhalation exposure to diazinon than was estimated by the air concentrations presented in Table II.

During the 40-minute spraying application of diazinon EC, PBZ air sampling of the applicator resulted in a diazinon concentration of 226 $\mu g/m^3$, which represents an 8-hour TWA concentration of 25 $\mu g/m^3$ (providing there was no additional exposure). Area air sampling in the same section begun 14 hours after completion of the spraying application measured diazinon concentrations ranging from 6.0 $\mu g/m^3$ to 52 $\mu g/m^3$ (Table III). These results suggest that greenhouse laborers who worked an entire 8-hour work shift in this section on the day after the pesticide application could have received essentially the same inhalation dose of diazinon as the applicator, who was exposed to a high concentration over a short period (53 minutes). The laborers would have been exposed to low concentrations over 8 hours. The diazinon air concentration immediately after completion of the application was not determined. Based on these sampling results, however, an unprotected worker entering the treated section immediately after the application was completed may have been at risk for inhalation exposure. Operation of air-circulating fans in Section 3 after the spraying application probably served to keep pesticide aerosols suspended, but the extent of the fans' influence on the levels of residual diazinon measured is unknown.

Section 170.110(c) of the EPA Worker Protection Standard requires that when a pesticide is applied as a smoke, mist, fog, or aerosol in a greenhouse, workers should be prohibited in the entire enclosed area (such as a section)

until specific ventilation criteria are met. Ventilation, either mechanical or passive, must "continue until the air concentration is measured to be equal to or less than the inhalation exposure level the labeling requires to be achieved."[8] Amended labels for pesticide products that have one specific restricted-entry interval applicable to all registered uses of the product on agricultural plants are required in section 156.208 to have the following statement: "Do not enter or allow worker entry into treated areas during the restricted-entry interval (REI) *of X hours* or *of X days* or *until the acceptable exposure level of X ppm* or *mg/m³ is reached.*"[10] No guidance was provided by EPA as to the required or recommended source(s) for inhalation exposure levels. "If no inhalation exposure level is listed on the labeling, ventilation shall continue until after 1) ten air exchanges are completed; 2) two hours of ventilation using fans or other mechanical ventilating systems; or 3) four hours of ventilation using vents, windows or other passive ventilation; or 4) eleven hours with no ventilation followed by one hour of mechanical ventilation; or 5) eleven hours with no ventilation followed by two hours of passive ventilation; or 6) twenty-four hours with no ventilation."[8]

Area air concentrations of diazinon measured during coldfogging operations in Section 4 of Plant 1 (Table IV) were substantially higher than area air concentrations measured during the spraying application in Section 3 (Table II). Consequently, area air sampling in Section 4 began almost 10 hours after completion of the coldfogging application measured 8-hour TWA concentrations which exceeded the exposure limit of diazinon (Table V). Substantial 8-hour TWA air concentrations were measured in Section 4 during the work shifts monitored on the Monday and Tuesday following the coldfogging application. Although these concentrations did not exceed the exposure limit for diazinon, they demonstrate the potential for residual insecticide exposure to greenhouse laborers for several work shifts after application. As mentioned earlier, operation of air-circulating fans in Sections 3 and 4 probably had some influence on the postapplication levels of residual diazinon measured. While the sampling results presented here are based on limited sampling at a single location, the results suggest that the EPA restricted-entry intervals may not be sufficient after coldfogging operations in greenhouses with passive ventilation.

The lowest area air concentration of chlorpyrifos (638 $\mu g/m^3$) measured in Section B-2 of Plant 2 during five hours of coldfogging represents an 8-hour TWA of 400 $\mu g/m^3$, which exceeds the exposure limit for chlorpyrifos. Area air concentrations measured in Section B-2 of Plant 2 during the period after the coldfogging application, when the exhaust fan was in operation (Table VI), and during the full-shift 8-hour sampling period immediately after the coldfogging application (Table VII) were all less than the exposure limit of chlorpyrifos. The exhaust fan was turned on 2 hours after the coldfogging application was completed, and operated for 2.5 hours; approximately ten air changes were completed during this period. Although these sampling results are also based on limited sampling at a single location, they suggest that the EPA restricted-entry intervals may be sufficient after coldfogging operations in greenhouses with mechanical exhaust ventilation systems.

Conclusions and Recommendations

PBZ air sampling of the applicator during a spraying application of diazinon resulted in the measurement of high concentrations during a brief application period of 40 minutes. Because of the risk associated with excessive inhalation and skin exposures to organophosphate and carbamate pesticides, each pesticide applicator at the greenhouse company should continue to wear a hooded disposable protective suit, industrial-grade latex gloves, rubber boots, and a NIOSH-approved full-facepiece respirator with pesticide cartridges when applying these types of pesticides. This same ensemble of personal protective equipment should also be worn by night watchmen or any other workers who enter a treated section during a restricted-entry interval. The use of respirators should be complemented by all components of a complete respiratory protection program in accordance with OSHA regulations and NIOSH recommendations. After every pesticide application, the applicator's disposable protective suit, gloves, and respirator cartridges should be placed in a garbage bag. Once the bag is closed, it should be placed immediately in a trash container for subsequent disposal in a landfill.

Area air sampling for diazinon conducted after spraying and coldfogging applications in greenhouse sections with passive ventilation systems demonstrated that workers at Plant 1 were at risk of inhalation exposure to residual pesticide concentrations. The results of area air sampling showed that diazinon concentrations measured after a spraying application of an EC formulation on a Friday evening declined over the weekend to low levels on Monday and Tuesday. Although measurable, postapplication air concentrations did not exceed the exposure limit for diazinon on Monday and Tuesday, when greenhouse laborers worked in treated sections. All spraying applications of insecticides should be conducted on Friday evenings, after greenhouse workers have left work, so that much of the residual pesticide aerosol can settle from the air over a weekend. In addition, applicators should consider the association between application rate and residual pesticide concentrations when planning a spraying application in sections of the greenhouse with passive ventilation and use the lowest feasible amount of pesticide that will still accomplish effective pest control. However, implementing these recommendations will not eliminate all exposures of greenhouse laborers to residual aerosolized pesticides. Therefore, installation of exhaust fans and sources of outside supply air to remove residual concentrations

after applications should be considered. Until installation of such equipment is completed, personal protection and administrative measures should be taken to protect employees from exposure to residual pesticides. Where feasible, the use of chemical pesticides should be reduced by including natural biological controls, such as parasites or predatory insects, as part of the company's overall pest management program.

Air concentrations of diazinon and chlorpyrifos exceeding the exposure limits for these insecticides were measured when no employees were in the monitored sections. High air concentrations occurred 1) during automatic coldfogging applications intentionally timed to occur when no one was in the greenhouse, and 2) on the day following the coldfogging application at Plant 1, the facility with passive ventilation. Considerable residual air concentrations of diazinon persisted throughout the weekend and during the work shifts on Monday and Tuesday following coldfogging applications in Section 4 of Plant 1. Mechanical exhaust ventilation operated immediately after a monitored coldfogging application at Plant 2 reduced air concentrations of chlorpyrifos to well below its exposure limit over a short period. Because substantial residual pesticide concentrations remained in the greenhouse section with passive ventilation after coldfogging applications, coldfogging should be discontinued at Plant 1 until exhaust fans and sources of outside supply air are installed.

References

1. National Institute for Occupational Safety and Health: Organophosphorus pesticides: Method 5600 (issued 8/15/93). In: NIOSH Manual of Analytical Methods, 4th rev. ed. National Institute for Occupational Safety and Health, Cincinnati, OH (in press).
2. Sine, C.: Farm Chemicals Handbook, Vol. 79. Meister Publishing Company, Willoughby, OH (1993).
3. Sine, C.: Farm Chemicals Handbook, Vol. 76, p. E 10. Meister Publishing Company, Willoughby, OH (1990).
4. National Institute for Occupational Safety and Health: NIOSH Recommendations for Occupational Safety and Health Compendium of Policy Documents and Statements. DHHS (NIOSH) Pub. No. 92-100. National Institute for Occupational Safety and Health, Cincinnati, OH (1992).
5. American Conference of Governmental Industrial Hygienists: 1992-1993 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. American Conference of Governmental Industrial Hygienists, Cincinnati, OH (1992).
6. Code of Federal Regulations: OSHA Table Z-1-A. 29 CFR 1910.1000. U.S. Government Printing Office, Washington, DC (1988).
7. Edelman, P.A.: Prevention of Injury by Pesticides. Chapter 9. In: Handbook of Pesticide Toxicology, Vol. 1, General Principles, p. 413. W.J. Hayes, Jr. and E.R. Laws, Jr., Eds. Academic Press, New York (1991).
8. Environmental Protection Agency: 40 CFR Part 170, Worker Protection Standard; Final Rule. Fed. Reg. 57:38151-38166 (August 21, 1992).
9. Bollinger, N.J.; Schultz, R.H.: NIOSH Guide to Industrial Respiratory Protection. DHHS (NIOSH) Pub. No. 87-116. National Institute for Occupational Safety and Health, Cincinnati, OH (1987).
10. Environmental Protection Agency: 40 CFR Part 156, Labeling Requirements for Pesticides and Devices; Amended Rule. Fed. Reg. 57:38146-38151 (August 21, 1992).

Editorial Note: Steve Lenhart and Melody Kawamoto are with the Hazard Evaluation and Technical Assistance Branch of NIOSH. More detailed information on this evaluation, including a description of the activities, findings, and recommendations associated with glove monitor sampling to evaluate hand exposures to pesticides by greenhouse workers, is contained in the Health Hazard Evaluation Report No. 92-022-2327 available through NIOSH, Hazard Evaluation and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, OH 45226; or by telephoning 1-800-35-NIOSH.