HETA 92-0022-2327
GREEN CIRCLE GROWERS, INC.
OBERLIN, OHIO

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

HETA 92-0022-2327
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NIOSH INVESTIGATORS:
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SUMMARY

The National Institute for Occupational Safety and Health (NIOSH) conducted a Health Hazard Evaluation (HHE) at Green Circle Growers, Inc., a greenhouse producer of floriculture and nursery products, in response to a confidential employee request concerning working conditions at Plant 4 in Columbia Station, Ohio. Industrial hygiene aspects included personal breathing-zone (PBZ) and 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. Sampling glove monitors were also used to evaluate the potential for skin exposure by greenhouse laborers to pesticide residues on plant leaves and in soil. Medical aspects included confidential interviews with 19 employees and a review of pseudocholinesterase (P-ChE) test results in company records.

Area air sampling conducted four days after high-volume spraying and coldfogging applications showed residual diazinon concentrations in greenhouse sections with passive ventilation systems. Operation of a mechanical exhaust ventilation system after a coldfogging application resulted in relatively low residual air concentrations of chlorpyrifos. Sampling for potential skin exposure showed diazinon in measurable quantities on the glove monitors of greenhouse laborers who handled plants treated with this insecticide 48 days earlier. When worn under latex gloves, only five (6%) of the sampling glove monitors showed detectable quantities of diazinon. Two of six medically monitored employees had evidence of greater than 30% decreases in P-ChE activity, and the decrease in another employee's P-ChE activity approached 30%, indicating possible overexposure to organophosphate or carbamate pesticides.

The findings of this HHE suggest that inhalation exposures to residual pesticides in the air after high-volume spraying and coldfogging applications and skin exposures to treated plants presented a health risk to Green Circle Grower employees at Plant 4. Recommendations include restricting the spraying applications to Friday evenings, discontinuing fogging applications until after installation of mechanical exhaust ventilation systems, requiring laborers to wear protective gloves when handling treated plants, and extending a modified medical monitoring program to all employees potentially exposed to pesticides.

Keywords: SIC 0181 (Ornamental Floriculture and Nursery Products), acetylcholinesterase, carbamates, chlorpyrifos (Dursban®), diazinon (Knox-out®), greenhouses, insecticides, organophosphates, pesticides.

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RESUMEN

El Instituto Nacional para Seguridad y Salud Ocupacional (National Institute for Occupational Safety and Health, NIOSH) condujo una evaluación de riesgos a la salud en respuesta a una petición confidencial de unos empleados sobre las condiciones de trabajo en la Planta 4 de Green Circle Growers, una empresa floricultura que cultiva plantas en invernaderos en Ohio. Aspectos de higiene industrial de la evaluación incluyeron muestreos del aire en unas secciones del invernadero y muestreos personales en la zona de respiración. Ambos tipos de muestras fueron tomados antes de, durante, y después de aplicaciones de rociado de alto volumen y aplicaciones de neblina de un insecticida organofosfatado (*diazinon*) en la Planta 4 en un invernadero que tiene un sistema pasivo de ventilación. Muestras del aire fueron tomadas durante y después de aplicaciones de neblina de un otro insecticida organofosfatado (*clorpyrifos*) en la Planta 1 en secciones de un invernadero que tiene un sistema mecánico de ventilación por extracción. Guantes de algodón usados durante el trabajo fueron analizados para evaluar la exposición potencial de piel a residuos de insecticida en las hojas de las plantas y en la tierra. Aspectos médicos de la evaluación incluyeron entrevistas confidenciales con 19 empleados y una revisión de los resultados de pruebas médicas en los registros de Green Circle Growers.

En el invernadero que tiene un sistema pasivo de ventilación, las muestras del aire mostraron concentraciones residuales de *diazinon* durante cuatro días después de la aplicación. En el otro invernadero, la operación del sistema mecánico de ventilación después de la aplicación de neblina de *clorpyrifos* resultó en concentraciones residuales relativamente bajas. Casi todos los guantes de algodón usados antes de la aplicación mostraron cantidades detectables o medibles de *diazinon*. La última aplicación previa fue aplicada 48 días antes. Por lo tanto, estos resultados indican que residuos de insecticida pueden estar presentes por muchos días después de las aplicaciones. Solo seis porciento de los guantes de algodón usados debajo de guantes de látex mostraron cantidades detectables de *diazinon*. Estos resultados indican que los guantes de látex podrían ser una medida efectiva de protección. Los resultados de la enzima plasmacolinesterasa (una prueba de sangre) de los empleados que aplicaron los insecticidas indican la posibilidad de exposiciones excesivas a los insecticidas organofosfatados o carbamatos.

Los descubrimientos de esta evaluación sugieron que los trabajadores de Green Circle Growers pudieron haber tenido exposiciones excesivas por inhalación a pesticidas residuales en el aire después de las aplicaciones, especialmente despues de las applicaciones de neblina en el invernadero con el sistema pasivo de ventilación. También pudieron haber tenido exposiciones excesivas de piel cuando manipulaban plantas que fueron tratadas con pesticidas. Exposiciones excesivas presentan riesgos a la salud de los empleados de Green Circle Growers. Las recomendaciones de NIOSH incluyen: 1) restringir las aplicaciones de rociado de insecticidas durante los días de trabajo; se deben aplicar solamente los viernes por la noche y se debe restringir la entrada a estas secciones sin protección hasta el lunes; 2) descontinuar las aplicaciones de neblina hasta que se termine la instalación de un sistema mecánico de ventilación por extracción; 3) Requerir que los trabajadores lleven guantes de protección cuando manipulen plantas que fueron tratadas con los pesticidas; y 4) Incluir a todos los empleados en un programa médico si tienen exposición potencial a insecticidas.

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) conducted a Health Hazard Evaluation (HHE) at Green Circle Growers, Inc., a greenhouse producer of floriculture and nursery products, in response to a confidential employee request. The requesters expressed concerns about working conditions at Plant 4 in Columbia Station, Ohio, specifically regarding: (1) adverse health effects (rashes and blisters on arms and legs, respiratory problems, bronchitis, severe and frequent headaches, blurred vision, stomach cramps, muscle weakness, mental confusion, dizziness, changes in heart rate, nausea, and diarrhea) believed to be associated with pesticide exposures; (2) exposure to asbestos cement sheets that are used as tops for plant benches in Sections 3 and 4; and (3) exposure to silica-containing materials used in the soil barn of the facility.

This final report describes the activities, findings, and recommendations associated with four site visits made by NIOSH investigators. An initial site visit took place on May 12, and May 13, 1992. In an opening meeting with Green Circle Growers representatives, an overview of the NIOSH HHE program was presented, and issues raised by the HHE request were discussed. Following the opening meeting, a walk-through survey was conducted to observe work practices and conditions throughout Plant 4. After the walk-through survey, personal breathing-zone (PBZ) and area air samples were collected in Section 3 during a spraying application of the organophosphate insecticide Knox-out® (diazinon). Area air samples for diazinon were also collected in Section 3 for the majority of the next day's work shift to estimate exposures of greenhouse workers reentering the treated bays. Confidential medical interviews were conducted with 19 employees, and company records of pseudocholinesterase test results were reviewed. A closing meeting with employer and employee representatives was held at the end of the visit.

A second site visit took place from July 17 to July 20, 1992, and involved additional PBZ and area air sampling for diazinon during and after a spraying application in Section 3, and also in Section 4, where an emulsifiable concentrate (EC) formulation of diazinon was applied by an automatic coldfogging method. At the request of the Green Circle Growers Operations Manager, sampling was also conducted at Plant 1, near Oberlin, Ohio, which was not included in the original HHE request. Plant 1 has exhaust fans for removing residual pesticide aerosols, in contrast with Plant 4, which has passive ventilation systems. At Plant 1, area air samples for Dursban® (chlorpyrifos), another organophosphate insecticide, were collected during and after a coldfogging application.

The third site visit took place from November 6 to November 10, 1992, and involved not only air sampling for diazinon, but also the use of sampling glove monitors to investigate the potential for skin exposure of greenhouse laborers to pesticide residues on plant leaves and in soil. During the final site visit on December 16, 1992, specimens of leaf sections from off-shore plant materials were collected for qualitative analysis for the presence of residual organophosphate and carbamate insecticides. Off-shore plant materials are grown in Costa Rican fields, then imported to Green Circle Growers for planting by greenhouse laborers working in the soil barn.

BACKGROUND

Green Circle Growers produces a variety of floriculture and nursery products such as bedding, seasonal and ornamental plants, and foliage. Production consists of 40% flowering potted plants, 35% potted foliage, and 25% ornamental bedding plants. In 1968, the company began operations with a few acres of Dutch and bench-type greenhouses for growing bedding plants. Initially, the growing season lasted only five months, from January to Memorial Day. With the addition of other plant varieties, growing seasons now require year-round operation. The company currently owns and operates five facilities totaling 60 acres, with 2,730,000 square feet of growing space. This production square footage under permanent, environmentally controlled greenhouses ranked Green Circle Growers as the eighth largest in the United States in this category of growers for the 1992 production year. Slightly more than half of the production greenhouses of Green Circle Growers are glass structures, and the remainder are gutter-connected double-polyethylene structures. Approximately 500 employees make up the full-time, permanent workforce. Approximately 60 full-time employees work at Plant 4 in floriculture production, and an additional ten employees are assigned to the wholesale and pick-up area. Approximately 150 full-time employees work at Plant 1. At Plant 1,seasonal demands in the spring and fall require the employment of an additional 150 temporary seasonal employees from the local job market.

A grower and two assistant growers are responsible for maintaining optimum growing conditions at Plant 4. Their tasks include preparing and applying all greenhouse chemicals. Two other employees, grower's helpers, are allowed to prepare and apply fungicides and growth regulators. Most of the remaining employees are classified as greenhouse labor. Their tasks include potting, watering, and cleaning plants. They can be assigned to any area of the greenhouse, as well as the soil barn, where imported and in-house plant cuttings are placed into plastic trays or plastic hanging baskets containing a mixture of sphagnum peat moss, styrofoam chips, and crushed limestone. The night watchmen are responsible for monitoring and maintaining greenhouse temperatures at night, in addition to security and night-time maintenance.

During the initial site visit, NIOSH investigators were given a list of 39 pesticides (1 herbicide, 1 bactericide, 15 fungicides, and 22 insecticides) and 6 growth regulators that had been or were in use at Plant 4 (Table I). The chemicals are listed in Table I according to common chemical name, with the trade name of each product used at Green Circle Growers shown in brackets. Occupational exposure limits exist for 12 of the 45 chemicals. Five organophosphate insecticides (acephate, chlorpyrifos, diazinon, dithio tepp, and oxydemeton-methyl) and five carbamate insecticides (aldicarb, bendiocarb, carbaryl, methomyl, and oxamyl) are listed. The remaining insecticides listed include chlorinated hydrocarbons, dithiocarbonates, a paraffinic oil, a pyrethroid, and neem oil (an extract from the neem plant native to India).

TABLE I

Pesticides and Growth Regulators[a]
Used at Plant 4

HERBICIDE	BACTERICIDE
Diquat*	Streptomycin [Agri-strep]

FUNGICIDES	
Benomyl* [Benlate]	Fosetyl-Al [Aliette]
Captan*	Iprodione [Chipco 26019]
Chlorothalonil [Daconil and Exotherm termil]	**Maneb*** [Manzate]
Dodemorph acetate [Milban]	Metalaxyl [Subdue]
Etridiazole [Truban]	Pentachloronitrobenzene [Terraclor]
Etridiazole and Thiophanate-methyl [Banrot]	Piperalin [Pipron]
	Thiophanate [Cleary 3336]
	Vinclozolin [Ornalin]

INSECTICIDES	
Abamectin [Avid]	Dicofol [Kelthane]
Acephate* [Orthene]	Dienochlor [Pentac]
Aldicarb [Temik]	Dithio tepp [Plant Fume 103]
Azadirachtin [Margosan-O]	**Endosulfan*** [Thiodan]
Bacillus thuringiensis [DiPel]	Fenpropathrin [Tame]
Bendiocarb [Dycarb]	Fluvalinate [Mavrik]
Bifenthrin [Talstar]	**Methomyl*** [Lannate]
Carbaryl* [Sevimol]	**Oxamyl*** [Vydate]
Chlorpyrifos* [Dursban]	**Paraffinic oil*** [Sunspray]
Demeton methyl [Metasystox]	Quinomethionate [Morestan]
Diazinon* [Knox-out and Clean Crop AG500]	

GROWTH REGULATORS	
Ancymidol [A-rest]	Gibberellic acid
Chlormequat-chloride [Cycocel]	Kinoprene [Enstar]
Daminozide [B-Nine]	Paclobutrazol [Bonzi]

* An occupational exposure limit exists for this chemical.
[a] Pesticides are listed alphabetically by common name; trade names are in brackets.

METHODS

Industrial Hygiene

Materials either stored or used in the soil barn were examined for evidence that they might contain silica. A sample of crushed limestone was collected in a glass vial and analyzed for quartz and cristobalite by X-ray diffraction. Two-milligram portions of the sample were weighed onto polyvinyl chloride filters prior to analysis. Samples were analyzed by NIOSH Method 7500[(1)] with the following modifications: (1) filters were disolved in tetrahydrofuran rather than being ashed in a furnace, (2) standards and samples were run concurrently, and (3) an external calibration curve was prepared from the integrated intensity rather than using the suggested normalized qualitative scan.

The condition of the asbestos cement sheets on plant benches were also examined. Two chips which had broken from one of the sheets were collected in a glass jar and analyzed for asbestos by polarized light microscopy. After ensuring homogeneity of the sample specimens, portions of the chips were immersed in Cargille liquids and examined with an Olympus polarized light microscope at a magnification of 100X. During the microscopic examination, qualitative identification and quantitation of the asbestos fibers were accomplished using a visual estimation technique.

Because of the potential for heat stress in greenhouses, which are built to retain heat and humidity, temperature and relative humidity were measured at various times during each site visit using a Vaisala HM 34 humidity and temperature meter (Vaisala, Inc., Woburn, Massachusetts). Weather forecasts for the days of the site visits did not predict conditions that were likely to cause heat stress in greenhouse employees. Therefore, extensive heat stress monitoring involving work-rate estimations and wet bulb globe thermometer (WBGT) measurements was not performed.

The initial site visit at Plant 4 was scheduled to coincide with an application of diazinon, an organophosphate insecticide, because some of the symptoms reported by the requesters were consistent with organophosphate exposure. In addition, diazinon has an established airborne exposure limit. To supplement information collected during the initial site visit, the second and third site visits were made during scheduled applications of diazinon. PBZ and area air samples were collected for diazinon during each of the first three site visits. Potential for exposure to the grower (job title of the applicator) was monitored by PBZ air sampling during spraying applications. The persistence of pesticides in the work environment, representing potential for exposure to other greenhouse workers, was evaluated by area air sampling after spraying and coldfogging applications. Area air sampling at Plant 4 reflected conditions of a passive ventilation system. Area air sampling for chlorpyrifos at Plant 1, conducted during the second site visit, reflected conditions of a dilution ventilation system; it also offered an opportunity to collect air sampling data on the persistence of another organophosphate insecticide that has an established airborne exposure limit.

Site Visit 1 [May 12-13, 1992]

During the first site visit, one PBZ and three area air samples were collected in Section 3 of Plant 4 during a one-hour application by high-volume spraying of Knox-out®, a microencapsulated formulation of diazinon. According to the Material Safety Data Sheet (MSDS) for Knox-out® 2FM Insecticide (Whitmire Research Laboratories, Inc., Philadelphia, Pennsylvania 19102), the product contains 23.0% diazinon. In preparation for spraying, the grower added 6 pints of Knox-out® to 100 gallons of water contained in one of the two holding tanks of the M85 Imovilli 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. During the application, the five air-circulating fans in the section were not operating, and the roof vents were closed. Warning signs in English and Spanish were posted on doors to the section before and during application. The signs listed the name of the pesticide applied, the time of application, and the time when reentry by unprotected individuals was permitted. On the day after application, four full-shift area air samples for diazinon were collected. The five air-circulating fans were operating and the roof vents were open during the post-application sampling period.

Air samples were collected for diazinon using ORBO® 49P tubes (Supelco, Inc., Supelco Park, Bellefonte, Pennsylvania 16823), which consist of a glass fiber filter and porous styrene-divinylbenzene copolymer adsorbent material (catalog number 2-0350N). During sampling, each ORBO® 49P sampling tube was connected by flexible tubing to a personal sampling pump operated at a flow rate of 1 liter per minute (Lpm). Each sampling tube was desorbed and analyzed according to NIOSH Method 5600[2] (draft) with modifications. Tubes were desorbed with 2.0 milliliters (ml) of toluene/acetone (90/10) at room temperature for 30 minutes followed by 30 minutes in a water-cooled ultrasonic bath. Analyses for diazinon were performed by gas chromatography (GC) with flame photometric detection (FPD) using a 30-meter (m) x 0.32-millimeter (mm) DB-1 capillary column with a 0.25-micrometer (µm) film. The oven was ramped from 125°C with no hold, to 220°C at 4°C per minute. A 3-microliter (µL) aliquot was injected into the GC using the splitless mode and an injector temperature of 250°C. The limit of detection and the limit of quantitation for the analyses were 0.04 microgram (µg)/sample and 0.12 µg/sample, respectively.

Site Visit 2 [July 17-20, 1992]

During the second site visit, one PBZ and five area air samples were collected in Section 3 during a one-hour application by high-volume spraying of Knox-out®. Conditions were the same as those of the previously sampled application, with the exception that 4, rather than 6, pints of Knox-out® were added to 100 gallons of water. In Section 4 (Bays A and B), which contained predominantly potted golden and marble queen pothos located on waist-high plant benches, two additional area air samples were collected during a four-hour application of an EC formulation of diazinon applied by an automatic coldfogging method using two Turbostar-E coldfogging machines (Agrodynamics, 12 Elkins Road, East Brunswick, New Jersey 08816). The hazardous ingredients identified in the MSDS for Clean Crop Diazinon AG500 Insecticide (Platte Chemical Company, Fremont, Nebraska 68025) are 48% diazinon and 36% xylene. Just before leaving the facility for the day, the grower added 1 liter (approximately 2 pints) of diazinon EC to 18 liters of water contained in a reservoir on each of two foggers located in Bays A and B of Section 4. The timers of these devices were set for night-time application to begin after the grower had left. The next day, the foggers were moved to Bays C and D of Section 4 for another night-time application of the same insecticide at the same rate as the previous night. Bays A and B are separated from Bays C and D by a barrier of clear plastic sheets that extends nearly to the floor. The walkway, however, is entirely open. Section 4, like Section 3, has a passive ventilation system. The roof vents were closed during the coldfogging application. Warning signs were posted on doors to the section before and during applications. Full-shift area air samples were collected at three locations in Section 3 and two locations in Section 4 during the first three consecutive days after the applications. In both sections, the air-circulating fans were operating and the roof vents were open during the post-application sampling periods.

Area air samples were also collected at five locations in Plant 1 during and immediately after a five-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 (Arimitsu Industry Company Limited, Japan). The hazardous ingredients identified in the MSDS for Dursban® 2E Insecticide (DowElanco, Indianapolis, Indiana 46268) are 24.1% chlorpyrifos and 75.9% other ingredients, which include xylene, 1,2,4-trimethylbenzene, cumene, and methyl chloroform. Plant 1 differs from Plant 4 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 the section 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 coldfogging application, the exhaust fans were not operated, the vent was closed, and the three air-circulating fans in the section were operated. For 2 hours after the application, no fans were operated, 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 the three air-circulating fans in Section B-2 were operated during each post-application sampling period.

Air samples were collected for diazinon at Plant 4 and for chlorpyrifos at Plant 1 using SKC® OSHA Versatile Sampler (OVS) sorbent tubes (SKC, Inc., Valley View Road, Eighty Four, Pennsylvania 15330), 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 Lpm. Tubes were desorbed and analyzed in a manner similar to the method described above (Site Visit 1) with the exception that the oven was ramped from 75°C with 0.5 minute hold, to 250°C at 25°C per minute. Each 3-µL aliquot was injected into the GC using the splitless mode and an injector temperature of 235°C. The limit of detection and the limit of quantitation for the diazinon analyses were 0.04 µg/sample and 0.2 µg/sample, respectively. The limit of detection and the limit of quantitation for the chlorpyrifos analyses were 0.04 µg/sample and 0.1 µg/sample, respectively.

Site Visit 3 [November 6-10, 1992]

Air Sampling

The air-sampling activities of the third site visit began with the collection of four area air samples in Section 3, four area air samples in Section 4, one area air sample in the break room, and one area air sample at a location between the break room and the entrance to Section 4 (just outside Section 5). These samples were collected during the work shift just prior to applications of diazinon in Sections 3 and 4. That evening, one PBZ and four area air samples were collected in Section 3 during a 40-minute application by high-volume spraying of the same EC formulation of diazinon (Clean Crop AG500) fogged in Section 4 during the second site visit. In preparation for spraying, the grower added 1.4 liters (approximately 3 pints) of Clean Crop AG500 to 100 gallons of water contained in one of the two holding tanks of the M85 Imovilli pumping equipment. Application conditions in Section 3 were the same as those of the previously monitored spraying applications during the first two site visits. After the spraying application and just before leaving the facility for the day, the grower added 1.4 liters of diazinon EC to 18 liters of water contained in a reservoir on each of two Turbostar-E 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 grower had left. The roof vents were closed and the air-circulating fans were off during the application. Area air samples for diazinon were collected hourly at four locations of Bays A and B during the application. Warning signs were posted on the doors to Sections 3 and 4 before and during applications. During the first four consecutive days after the applications, full-shift area air samples were collected at four locations in Section 3, four locations in Section 4, and two locations in and near the break room. In both sections, the air-circulating fans were continuously operating and the roof vents were occasionally open during the post-application sampling periods.

Air samples were collected for diazinon at Plant 4 using SKC® OVS sorbent tubes. During sampling, each OVS sorbent tube was connected by flexible tubing to a personal sampling pump operated at a flow rate of 1 Lpm. After sampling, the tubes were mailed to the NIOSH contract laboratory for analysis. Tubes were desorbed and analyzed in a manner similar to the methods described above (Site Visits 1 and 2) with the exception that the oven was ramped from 80°C with a 1 minute hold to 230°C at 20°C per minute. Each 3-µL aliquot was injected into the GC using the splitless mode and an injector temperature of 250°C. The 96 OVS sorbent tubes collected during this site visit were divided for analysis into five sets. The limits of detection were 0.2 µg/sample for three sets and 0.3 µg/sample for two sets. The limits of quantitation for the diazinon analyses of the five sets ranged from 0.06 µg/sample to 1.0 µg/sample.

Glove Monitor Sampling

During the third site visit, five greenhouse laborers wore sampling glove monitors to investigate the potential for skin exposure to pesticide residues on plant leaves and in soil. Five other greenhouse laborers also wore sampling glove monitors under industrial-grade latex gloves to investigate the likelihood that latex gloves are effective barriers to skin exposure. Full-shift skin exposure sampling was performed during the work shift prior to diazinon applications in Sections 3 and 4, and during the work shifts on Monday and Tuesday, the third and fourth days after the applications. The light-weight glove monitors consisted of 65% polyester and 35% cotton. Three pairs of gloves were worn by each worker on each day of testing. Gloves were worn: (1) from the start of a work shift to the beginning of the morning break period, (2) from the end of the break period to the beginning of the lunch period, and (3) from the end of the lunch period to the end of the work shift. Care was taken to avoid contamination of the sampling glove monitors during removal. For those employees wearing latex gloves over the glove monitors, the latex gloves were discarded by the employee, then a NIOSH investigator wearing latex gloves removed each inner glove monitor and placed it directly into a 120-ml opaque glass jar with a teflon®-lined cap. Other NIOSH investigators wearing latex gloves removed the sampling glove monitors from the employees who did not wear latex gloves, then placed the monitors in the same type of jars. For each employee, left and right glove monitors were placed into separate jars for separate analyses.

After each day of sampling, the jars containing sampling glove monitors were packaged for next-day delivery to the NIOSH contract laboratory for diazinon analysis. The desorption process involved shaking each glove in 20 ml of toluene/acetone (90/10) at room temperature for at least 1 hour. Analyses for diazinon were performed by GC with FPD using a 30 m x 0.25 mm DB-5 fused silica capillary column coated internally with a 0.25 µm film. The oven was ramped from 80°C with a 1-minute hold to 230°C at 20°C/minute. The limits of detection were 2 µg/sample for the sample sets collected on November 6 and on November 9, and 3 µg/sample for the sample set collected on November 10. The limits of quantitation were 8 µg/sample for the sample sets collected on November 6 and on November 9, and 10 µg/sample for the sample set collected on November 10.

Site Visit 4 [December 16, 1992]

During the fourth site visit at Plant 4, leaf sections of off-shore (imported) plant materials were collected for analysis of residual organophosphate and carbamate insecticides. Off-shore leaf materials are grown in Costa Rican fields, then shipped to Green Circle Growers for planting by greenhouse labor working in the soil barn. Although Green Circle Growers knows that pesticides are applied to plants in off-shore fields, the specific chemicals used are not known. During the site visit, leaf sections of philodendron and golden pothos were collected for subsequent analysis. Five to seven leaves were randomly removed from each of four shipment boxes. The leaves were stacked, then rectangular sections were cut from the leaves with scissors. Each section was then placed directly into wide-mouth glass jars. This step was repeated until the desired number of leaves was collected. Two jars of each plant type were collected. The NIOSH investigator wore industrial-grade latex gloves throughout the leaf collection process and changed gloves between sample sets. To extract organophosphate and carbamate pesticides from the leaf sections, 20 ml of acetonitrile was added to each sample jar and the jar was shaken for 30 minutes. The extracts were transferred to teflon-sealed glass test tubes and suspended matter was allowed to settle. Three-µl aliquots of supernate were taken for analysis by GC with FPD using a 30 m x 0.25 mm DB-1 fused silica capillary column coated internally with a 0.25 µm film. The oven was ramped from 100°C with no hold, to 265°C at 3°C/minute. Each sample was screened for 29 organophosphate pesticides; the limits of detection for these analytes ranged from 10 µg/sample to 150 µg/sample. Carbamate analyses were performed by high performance liquid chromatography according to EPA method 8318[3] with modifications. Each sample was screened for 10 carbamate pesticides; the limits of detection for these analytes ranged from 1 µg/sample to 22 µg/sample.

During the same site visit, eight sampling glove monitors were worn for 80 minutes by four greenhouse laborers in the soil barn while they planted golden pothos. This sampling was done to investigate the potential for skin exposure to pesticide residues that might be on the off-shore plant material. The light-weight gloves used for sampling consisted of 65% polyester and 35% cotton. At the end of the sampling period, each glove monitor was removed by the NIOSH investigator and placed directly into a 120-ml opaque glass jar with a teflon®-lined cap. These samples were withheld from analysis until completion of the leaf analyses, at which time they were desorbed by shaking them for 30 minutes in 100 ml of acetonitrile and were analyzed for aldicarb sulfone and oxamyl by high-performance liquid chromatography using EPA Method 8318[3] with modifications. The limit of detection was 5 µg/sample, and the limit of quantitation was 16 µg/sample for both analytes.

Medical

Nineteen of 57 employees at Plant 4 were confidentially interviewed during the first site visit (Table II). All job titles except supervisors and management personnel were represented. Nine (19%) of the forty-seven greenhouse laborers were randomly selected from different seniority levels. All of the employees in the remaining job titles were interviewed; fewer than four employees were assigned to each of these job titles. The interviewers solicited information about work (job tasks, work exposures, training, and medical monitoring) and health (symptoms of pesticide toxicity experienced in the previous month, skin conditions, and heat stress). During the confidential employee interviews, some of the greenhouse workers were noted to speak and read only Spanish. For those individuals, interviews were conducted in Spanish. A screening inspection of the hands and forearms was performed on interviewed employees to detect potential work-related skin lesions.

TABLE II

Confidential Employee Interviews
Plant 4
May 13, 1992

Job title	Number interviewed	Total number employed
Grower or assistant grower[a]	3	3
Grower's helper[b]	2	2
Cleaner	1	1
Greenhouse laborer	9	47
Maintenance	1	1
Shipping	1	1
Night watchman	2	2

[a]Job tasks include application of all chemicals.
[b]Job tasks include application of a limited number of chemicals, such as fungicides and growth regulators, but not insecticides.

The Occupational Safety and Health Administration (OSHA) Form 200 (Log and Summary of Occupational Injuries and Illnesses) for Plant 4 from January 1990 through April 1992, was reviewed. In addition, laboratory reports for employees undergoing cholinesterase monitoring were reviewed.

EVALUATION CRITERIA

General Guidelines

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH investigators employ environmental evaluation criteria for assessment of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours/day, 40 hours/week for a working lifetime without experiencing adverse health effects. It is important to note, however, that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the levels established by the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus the overall exposure may be increased above measured airborne concentrations. Evaluation criteria typically change over time as new information on the toxic effects of an agent become available.

The primary sources of evaluation criteria for the workplace are: NIOSH Criteria Documents and Recommended Exposure Limits (RELs),[(4)] the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs),[(5)] and the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[(6)] These values are usually based on a time-weighted average (TWA) exposure, which refers to the average airborne concentration of a substance over an entire 8- to 10-hour workday. Concentrations are usually expressed in parts per million (ppm), milligrams per cubic meter (mg/m^3), or micrograms per cubic meter ($\mu g/m^3$). In addition, some substances have only a ceiling limit, a concentration that should not be exceeded during any part of a workday. Other substances have a short-term exposure limit (STEL) to supplement a TWA limit where there are recognized toxic effects from short-term exposures. A STEL is a 15-minute TWA concentration which should not be exceeded at any time during a workday even if the 8-hour TWA is less than the exposure limit. The ACGIH recommendation for a substance without a STEL is that "excursions in worker exposure levels may exceed 3 times the TLV-TWA for no more than a total of 30 minutes during a workday, and under no circumstancesshould they exceed 5 times the TLV-TWA, provided that the TLV-TWA is not exceeded."[(5)] The basic concept is that excursions above a substance's 8-hour TWA exposure limit should be maintained within reasonable limits in well-controlled processes.

NIOSH RELs are based primarily on the prevention of occupational disease. In contrast, PELs and other OSHA standards are required to take into account the economic feasibility of reducing exposures in affected industries, public notice and comment, and judicial review. In evaluating worker exposure levels and NIOSH recommendations for reducing exposures, it should be noted that employers are legally required to meet OSHA standards.

Crystalline Silica

Crystalline silica, commonly referred to as free silica, is defined as silicon dioxide (SiO_2) molecules arranged in a fixed pattern, as opposed to a nonperiodic, random molecular arrangement referred to as amorphous silica. The three most common forms of crystalline silica encountered in industry are quartz, tridymite, and cristobalite, with quartz being by far the most common form. The principle adverse health effect of crystalline silica is the dust-related respiratory disease, silicosis. Silicosis is a form of diffuse interstitial pulmonary fibrosis resulting from the deposition of respirable crystalline silica in the lung. Conditions of exposure may affect both the occurrence and severity of the disease. Although silicosis usually occurs after fifteen or more years of exposure, latentcy periods of only a few years are well recognized and are associated with intense exposures to respirable dust high in crystalline silica. In its early stages, simple silicosis usually produces no symptoms. However, both acute silicosis (a different disease process associated with repeated high exposures) and complicated silicosis (progressive massive fibrosis) are associated with shortness of breath, intolerance for exercise, and a marked reduction in measured pulmonary function. Diagnosis is most often based on a history of occupational exposure to crystalline silica and the characteristic appearance of the disease on chest X-rays. Respiratory failure and premature death may occur in advanced forms of the disease. Individuals with silicosis are also at increased risk of developing tuberculosis. No specific treatment is available for silicosis, and the disease may progress even after the worker's exposure to silica has ceased.[(7)]

Epidemiological studies have shown an association between silicosis and lung cancer.[(8-10)] The International Agency for Research on Cancer (IARC) reviewed the data regarding crystalline silica and determined that there is sufficient evidence for the carcinogenicity in laboratory animals and limited evidence for human carcinogenicity.[(11)] Because these data meet the OSHA definition of a potential occupational carcinogen as defined in 29 CFR 1990, NIOSH revised its policy on crystalline silica exposure criteria and recommended that OSHA consider crystalline silica as a potential occupational carcinogen.[(12)] (NIOSH is currently conducting another review of the data on carcinogenicity.)

The ACGIH TLV for crystalline silica (cristobalite and tridymite) as quartz (respirable dust) is 0.05 mg/m^3 as an 8-hour TWA.[(5)] The ACGIH TLV for crystalline silica (crystalline quartz) as quartz (respirable dust) is 0.1 mg/m^3 as an 8-hour TWA.[(5)] The OSHA PELs for crystalline silica, as revised in 1989 under the Air Contaminants Standard, were identical to the ACGIH TLVs.[(6)] However, in 1992, the 11th Circuit Court of Appeals vacated the 1989 Air Contaminants Standard, and Federal OSHA is currently enforcing the previous transitional limits for crystalline silica.[(6)] Some states operating their own OSHA-approved job safety and health compliance programs may continue to enforce the 1989 limits (which are identical to the current ACGIH TLVs). The NIOSH REL for respirable crystalline silica is 0.05 mg/m^3 as a TWA for up to 10 hours per day during a 40-hour work week.[(4)] This REL is intended to prevent silicosis.

Asbestos Cement Sheets

Numerous studies of workers exposed to asbestos have demonstrated an excess of asbestos-related disease, including lung and other cancers. NIOSH recommends as a goal, the elimination of asbestos exposure in the workplace, and where it cannot be eliminated, that occupational exposure to airborne asbestos be limited to the lowest feasible concentration.(13) This recommendation is based on the proven carcinogenicity of asbestos in humans and on the absence of a known safe threshold concentration. NIOSH contends that there is no safe concentration for airborne asbestos exposure. Therefore, any detectable air concentration of asbestos in the workplace warrants further evaluation and, if necessary, the implementation of measures to either eliminate or control exposures.

The OSHA PEL for asbestos limits exposure to 0.2 fiber/cubic centimeter (cc) as an 8-hour TWA.(14) OSHA has also established an asbestos excursion limit for the construction industry that restricts worker exposures to 1.0 fiber/cc averaged over a 30-minute exposure period.(15) Asbestos cement sheets contain asbestos (10-50%) and portland cement, and are classified by EPA as a Category II miscellaneous, nonfriable asbestos-containing material (ACM).(16) Nonfriable ACM describes "any material containing more than 1% asbestos that when dry *cannot* be crumbled, pulverized, or reduced to powder by hand pressure."(16) EPA has determined, however, that "if severely damaged, otherwise nonfriable materials can release significant amounts of asbestos fibers."(16) Asbestos fibers can also be released from asbestos cement sheets during activities such as sanding, drilling, grinding, or cutting, unless proper precautions to control fiber release are implemented.

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.(17) Knox-out® 2FM is a flowable microencapsulated formulation of diazinon used for residual control of ants, carpet beetles, crickets, cockroaches, fleas, flies, greenhouse pests, stored-product pests, ticks, and silverfish in and around buildings, including food handling establishments, greenhouses, food warehouses, processing plants, and transportation equipment.(17) Because its half-life of in soil is 30 days, it is considered a moderately persistent insecticide.(18) The NIOSH REL and the ACGIH TLV for diazinon are 100 $\mu g/m^3$ (8-hour TWA). The TLV has a "skin" notation,(4, 5) 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 PEL for diazinon prior to the 1989 Air Contaminants Standard,(6, 19) 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, 19] Depending upon the formulation, diazinon-containing insecticides are classified under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) as category II, III, or IV.[17] FIFRA categories are equivalent to toxicity ratings ranging from extremely toxic (category I) to practically nontoxic (category IV).[20]

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.[17] Because its half-life in soil is 30 days, it is considered a moderately persistent insecticide.[18] 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] OSHA did not have a PEL for chlorpyrifos prior to the 1989 Air Contaminants Standard,[6, 19] 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 200 $\mu g/m^3$ limit.[6, 19] Chlorpyrifos-containing insecticides are classified as FIFRA category II pesticides.[17]

Biological Monitoring

Organophosphate insecticides typically cause illnesses in humans by binding to and inhibiting acetylcholinesterases (A-ChE) at nerve endings. A-ChE is a ChE enzyme that metabolizes, and thus controls, the amount of acetylcholine (nerve impulse transmitter) available for transmitting nerve impulses. Inhibition of A-ChE causes acetylcholine to accumulate at nerve endings, resulting in increased and continued acetylcholine stimulation at those sites. Symptoms of A-ChE inhibition include the following:

increased sweating	chest pain	muscle weakness
blurred vision	breathing difficulty	muscle twitches
increased tears	wheezing	memory problems
increased saliva	nausea and vomiting	decreased concentration
increased nasal and lung secretions	abdominal cramps	diarrhea

The organophosphate-ChE bond is stable and largely irreversible, so recovery of ChE activity depends on the generation of new ChE. ChE inhibition, therefore, can sometimes last for months.ChE inhibition can be measured as decreases in ChE activity. Red blood cell cholinesterase (RBC-ChE), like ChE in nerve tissues, is an A-ChE. Its rate of regeneration nearly parallels that of A-ChE in nerve tissues, making its measurement a useful method of biologically monitoring exposure to organophosphate insecticides. A significant decrease in RBC-ChE activity indicates either a recent excessive exposure or repeated exposures to amounts sufficient to depress ChE activity before recovery is complete. Other types of cholinesterases, such as plasma cholinesterase or pseudocholinesterase (P-ChE), are more sensitive to organophosphate inhibition. P-ChE activity, however, returns to baseline values earlier than RBC-ChE activity. Therefore, P-ChE values may not reflect the severity of toxicity unless blood specimens are obtained soon after exposure. P-ChE activity can also be affected by factors unrelated to organophosphate exposure, including medical conditions such as liver disease.(21) P-ChE activity is clinically useful in monitoring cases of severe organophosphate poisoning, but its use in monitoring workplace exposures is limited.

For employees with potential for occupational exposure during the manufacture and formulation of pesticides, NIOSH recommends that RBC-ChE activity be measured.(22) The range of RBC-ChE activity varies considerably among individuals who have not been exposed to organophosphate insecticides. Thus, an individual could experience a toxic decrease in RBC-ChE activity and still be within the range of values found in the general population ("normal" or reference range). For this reason, a single value within the laboratory's reference range should not necessarily be interpreted as a "normal" value. Instead, toxicity should be determined by comparing a given value with the individual's baseline value. Therefore, the NIOSH recommendations for medical monitoring of potentially exposed workers in the manufacture and formulation of pesticides include a baseline measurement of RBC-ChE activity before potential for exposure begins and periodic measurements at least annually after potential for exposure begins.(22) NIOSH recommends that measurements of periodic RBC-ChE activity be made available as frequently as once a week for employees who are potentially exposed to ChE-inhibiting insecticides.(22) The testing frequency may be initially increased to as often as every day, or, after three determinations, may be decreased to as infrequently as every eight weeks.(22) The frequency should be based on the decision of a responsible medical practitioner after consideration of the following for each employee: (1) The toxicity of the pesticides to which the employee may be exposed; (2) The potential duration and concentration of the pesticide exposure; (3) The state of health of the employee; and (4) The results of previous RBC-ChE determinations.(22)
NIOSH defines an unacceptable exposure to organophosphate insecticide as a decrease in RBC-ChE activity to below 70% of the baseline value.(22)

The Biological Exposure Index (BEI) adopted by the ACGIH for exposure to organophosphate chemicals is an RBC-ChE activity equal to 70% of an individual's baseline.(23) The BEI represents the level of determinant which is most likely to be observed in specimens collected from a healthy worker who has been exposed to chemicals to the same extent as a worker with inhalation exposure to the TLV-TWA. BEIs apply to 8-hour exposures, five days per week. ACGIH regards biological monitoring as complementary to air monitoring and not for use as a measure of adverse effects or for diagnosis of occupational illness.(5,23)

For workers without a baseline RBC-ChE value, repeated tests have been recommended after removal from exposure to determine the level at which RBC-ChE values stabilize.(24,25) RBC-ChE values, however, may continue to increase for several months after last exposure. Therefore, RBC-ChE values should not be considered baseline until they have stabilized. To ensure validity, tests should be performed by the same laboratory using the same analytic method.

Exposure to carbamate insecticides, which are not organophosphate chemicals, can also cause ChE inhibition and its symptoms. Unlike the organophosphate-ChE bond, the carbamate-ChE bond is rapidly broken. Therefore, the effects of carbamate exposure last for a much shorter time than that of organophosphate exposure. For the same reason, biological monitoring of RBC-ChE activity may not necessarily reflect exposure to carbamate insecticides.

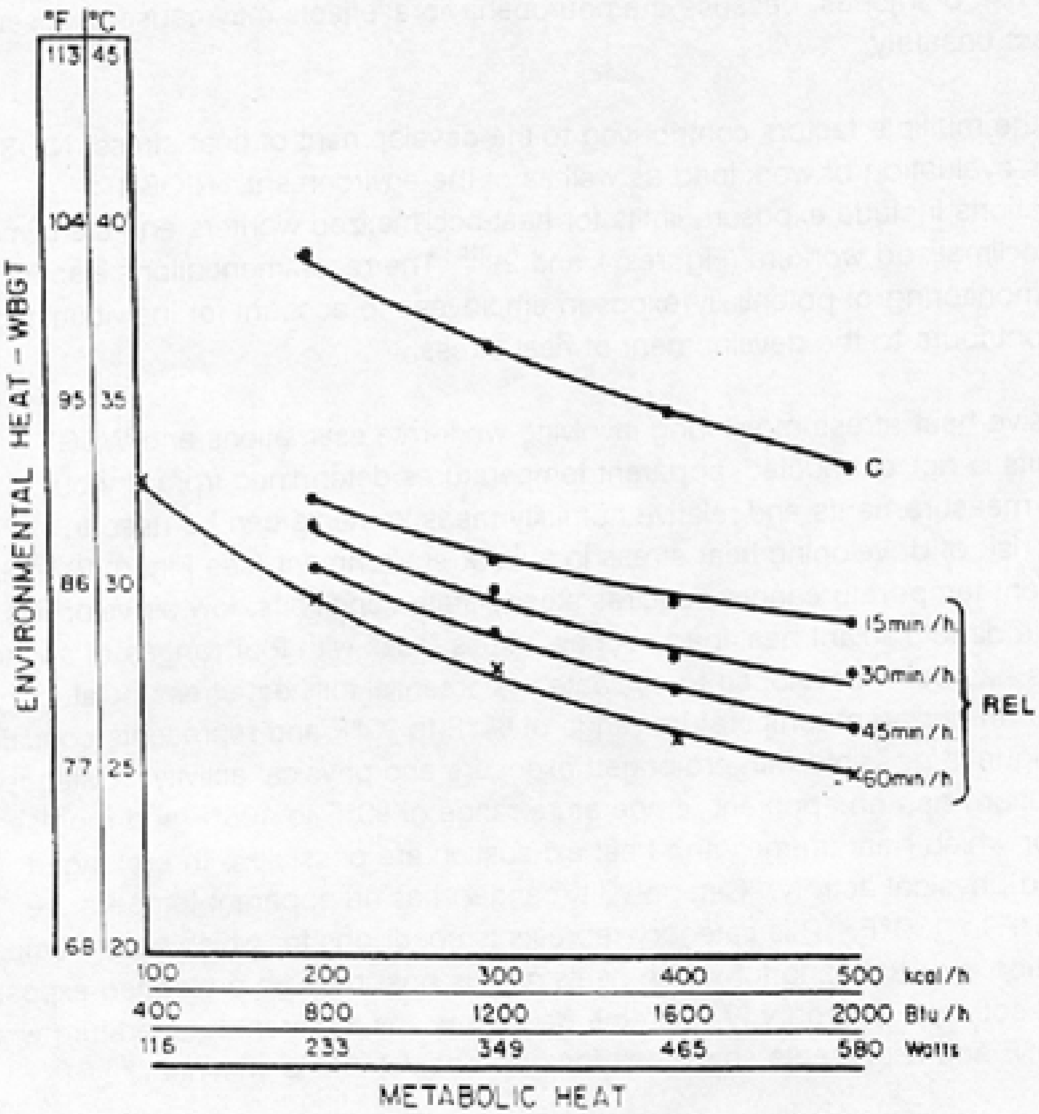
Heat Stress

Many factors contribute to heat stress. Measurable environmental factors include air temperature, air velocity, relative humidity, and radiant temperature. Human factors and individual factors, such as work load, are more difficult to determine. Susceptibility to heat stress can be affected by factors such as age, state of health, physical conditioning, and acclimatization to heat. Certain conditions, such as acute illness, increase in work load, acute dehydration (including heavy sweating from physical exertion), lack of sleep, and drinking alcohol, may increase the risk for heat stress even in acclimatized workers. Symptoms of heat exhaustion, a mild form of heat stress, include headache, nausea, dizziness, weakness, thirst, and giddiness. These symptoms may also occur in the early stage of heatstroke, the most severe heat-related disorder. Heatstroke can result in death and is, therefore, a medical emergency. Late signs of heatstroke include alterations of consciousness, lack of sweating, and core body temperatures in excess of 105.8°F.(26) Heat stress, even in its mildest forms, can also increase the risk of injuries, because the neurobehavioral effects may cause exposed workers to act unsafely.

Because of the multiple factors contributing to the development of heat stress, NIOSH recommends evaluation of work load as well as of the environment. NIOSH recommendations include exposure limits for heat-acclimatized workers and alert limits for heat-unacclimatized workers (Figures 1 and 2).(26) The recommendations also include physiologic monitoring of potentially exposed employees to account for individual factors that could contribute to the development of heat stress.

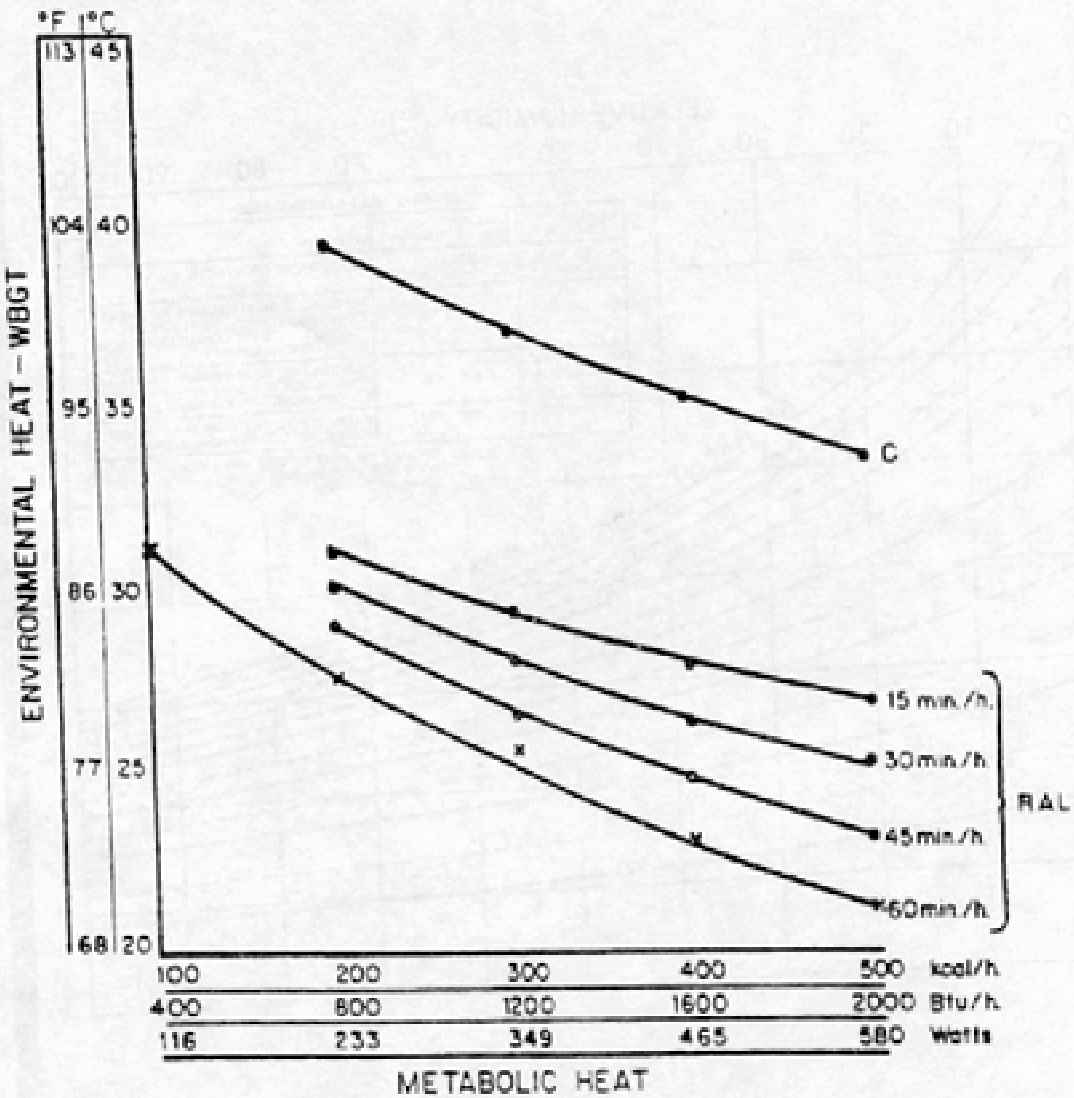
When extensive heat stress monitoring involving work-rate estimations and WBGT measurements is not conducted, apparent temperatures determined from dry bulb temperature measurements and relative humidity measurements can be used to evaluate the risk of developing heat stress in a work environment (see Figure 3).(27) Use of the apparent temperature index requires steady-state conditions, low air velocities, and negligible direct radiant heat load. A heat stress index with four ranges of apparent temperatures has been developed to evaluate the potential for heat stress. Category I (caution) has an apparent temperature range of 80°F to 90°F and represents conditions for which fatigue is possible with prolonged exposure and physical activity. Category II (extreme caution) has an apparent temperature range of 90°F to 105°F and represents conditions for which heat cramps and heat exhaustion are possible with prolonged exposure and physical activity. Category III (danger) has an apparent temperature range of 105°F to 130°F. This category represents conditions for which heat cramps or heat exhaustion are likely and for which heatstroke is possible with prolonged exposure and physical activity. Category IV (extreme danger) is any apparent temperature which exceeds 130°F and represents conditions for which heatstroke is imminent.(27)

Figure 1. NIOSH Recommended Heat-Stress Exposure Limits for Heat-Acclimated Workers.[58]



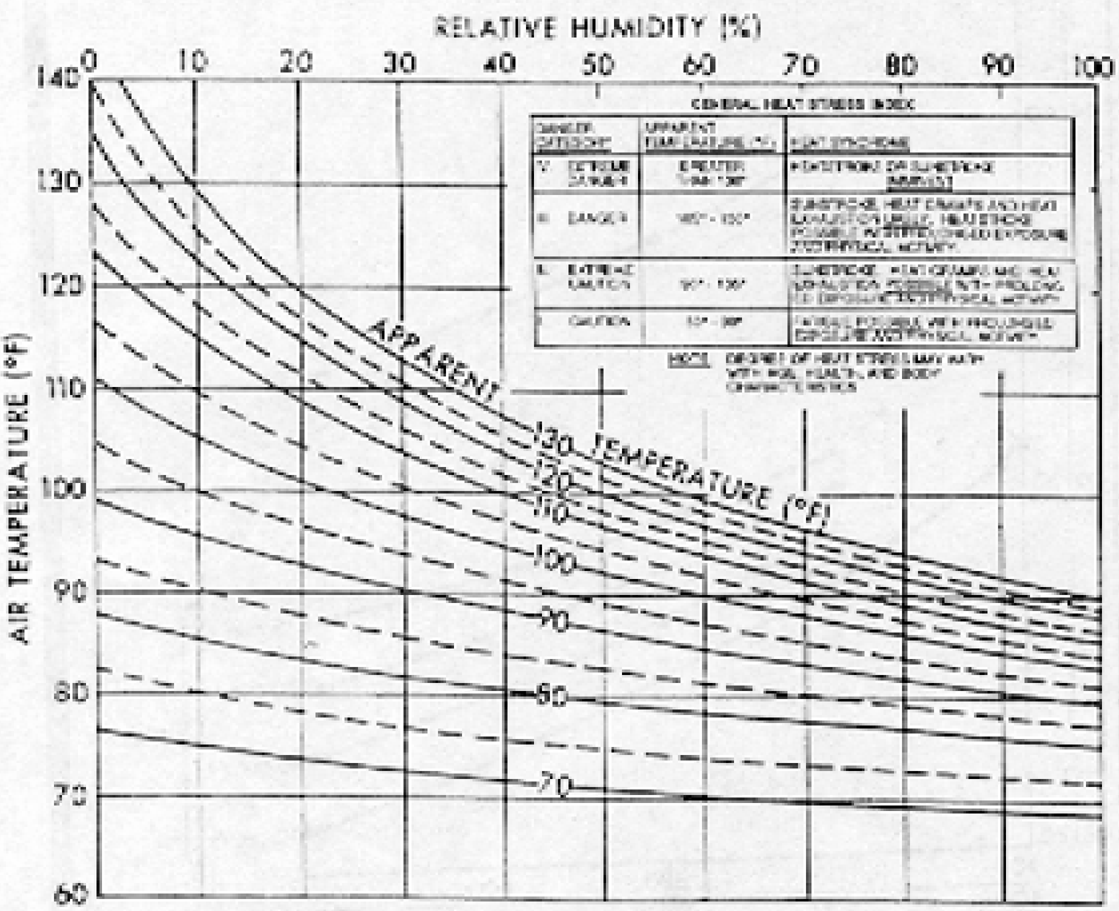
C = Ceiling Limit
REL = Recommended Exposure Limit
*For "standard worker" of 70 kg (154 lbs) body weight and 1.8 m^2 (19.4 ft^2) body surface.

Figure 2. NIOSH Recommended Heat-Stress Exposure Limits for Heat-Unacclimatized Workers.[26]



C = Ceiling Limit
RAL = Recommended Alert Limit
*For "standard worker" of 70 kg (154 lbs) body weight and 1.8 m^2 (19.4 ft^2) body surface.

Figure 3. Apparent Temperature as a Function of Air Temerpature and Relative Humidty.[23]



RESULTS

Industrial Hygiene

The sample of crushed limestone collected from the soil barn had a quartz content of 1.8%; the cristobalite content was reported as non-detectable. The limits of detection and the limits of quantitation for both substances were 0.75% and 1.5%, respectively. Although broken and cracked asbestos cement sheets were observed in Sections 3 and 4, no asbestos cement sheets were seen that were friable. The samples of asbestos cement sheets contained 15% chrysotile asbestos.

Dry bulb temperatures and relative humidity values measured during both site visits are presented as footnotes in Tables III through X and XII through XVI. The highest temperature recorded was 87°F measured on May 12, 1992; the highest relative humidity recorded was 95% measured on July 17, 1992. Based on the heat stress index of apparent temperatures,[27] each set of measurements which includes a dry bulb temperature of 80°F or higher represents a category I heat stress risk (caution: fatigue possible with prolonged exposure and physical activity).

TABLE III

Results of Personal and Area Air Sampling for Diazinon
[Spraying Application of Knox-out®]
Plant 4, Section 3
Site Visit 1 [May 12 - 13, 1992]

Sampling Location	Sampling Period	Sampling Duration (minutes)	Diazinon Concentration (µg/m³) Actual	Diazinon Concentration (µg/m³) 8-hour TWA*
May 12, 1992				
On Applicator	1642 - 1756	74	116	17.9
Bay B (South Wall)	1646 - 1804	78	67.9	11.0
Bay B (Main Walk)	1645 - 1802	77	24.7	4.0
Bay C (North Wall)	1649 - 1803	74	66.2	10.2
May 13, 1992				
Bay B (South Wall)	0814 - 1414	360	16.1	12.1
Bay B (Main Walk)	0805 - 1405	360	21.1	15.8
Bay C (North Wall)	0808 - 1408	360	19.4	14.6
Near Entrance	0802 - 1402	360	13.3	10.0

Temperature = 87°F and relative humidity = 37% at 1700 hours on May 12.
Temperature = 70°F and relative humidity = 86% at 1200 hours on May 13.

µg/m³: micrograms per cubic meter.
8-hour TWA: 8-hour time-weighted average.

*Calculated assuming no exposure during the unsampled portion of the work shift.

Site Visit 1 [May 12-13, 1992]

The results of air sampling for diazinon during the first site visit are presented in Table III. The results of one PBZ sample and three area air samples collected during the spraying application on May 12, 1992, are shown, along with the results of four area air samples collected the next day, when sampling was conducted for six hours of the 8-hour work shift. Diazinon concentrations shown under the "Actual" heading for May 12, 1992, represent exposure estimates for the duration of the application only. Eight-hour TWA concentrations calculated assuming no diazinon exposure for the remaining (unsampled) portion of an 8-hour work shift are also presented. In this case, the 8-hour TWA concentrations are more appropriate than the actual concentrations for comparison with the exposure limit of diazinon, since the applicator left the facility after the application.

Diazinon concentrations shown under the "Actual" heading for May 13, 1992, can reasonably be interpreted to be estimates of exposure for the entire 8-hour work shift, since diazinon levels during the unsampled portion of the work shift were likely to be similar to those measured during the sampled portion. Eight-hour TWA concentrations calculated assuming that there was no exposure to diazinon during the unsampled portion of the shift are also presented in Table III. In this case, however, the "actual" diazinon concentrations are more appropriate than the 8-hour TWA concentrations for comparison with the exposure limit of diazinon. Two of the area air concentrations (21.1 µg/m^3 and 19.4 µg/m^3) measured on the day after the insecticide application exceeded the 8-hour TWA concentration (17.9 µg/m^3) measured on the applicator while spraying.

TABLE IV

Results of Area Air Sampling for Diazinon [Pre-application]
Plant 4, Section 3
Site Visit 2 [July 17, 1992]

Sampling Location	Sampling Period	Sampling Duration (minutes)	Diazinon Concentration (µg/m^3)
Near door to break room	1113 - 1518	245	(0.4)
Bay A (North Wall)	1148 - 1528	220	(0.9)
Bay B (South Wall)	1136 - 1524	228	(0.9)
Entrance to Section 5	1104 - 1516	252	(0.8)
Section 2	1122 - 1522	240	(0.8)

Temperature = 74°F and relative humidity = 93% at 1200 hours.

Note: Values in ( ) represent concentrations of diazinon between the minimum detectable concentration (0.2 µg/m^3) and the minimum quantifiable concentration (0.8 µg/m^3) based on 4-hour sampling durations; they should be considered trace concentrations.

µg/m^3: micrograms per cubic meter.

Site Visit 2 [July 17-20, 1992]

The results of air sampling for diazinon in Section 3 of Plant 4 during the second site visit are presented in Tables IV, V, and VI. Area air sampling conducted on

July 17 during the work shift just prior to the spraying application of Knox-out® (Table IV) revealed trace concentrations of residual diazinon in the air, presumably from the last application of this insecticide on May 12. The results of a PBZ sample and five area air samples collected during the spraying application of Knox-out® in July are shown in

TABLE V

Results of Personal and Area Air Sampling for Diazinon
[Spraying Application of Knox-out®]
Plant 4, Section 3
Site Visit 2 [July 17, 1992]

Sampling Location	Sampling		Diazinon Concentration (µg/m³)	
	Period	Duration (minutes)	Actual	8-hour TWA*
On applicator	1543 - 1636	53	18.9	2.08
Near door to break room	1546 - 1643	57	17.2	2.04
Bay A (North Wall)	1550 - 1650	60	28.3	3.54
Bay B (South Wall)	1549 - 1647	58	13.3	1.60
Entrance to Section 5	1545 - 1639	54	4.1	0.46
Section 2	1547 - 1544	57	6.3	0.75

Temperature = 75°F and relative humidity = 95% at 1600 hours.
µg/m³: micrograms per cubic meter.
8-hour TWA: 8-hour time weighted average.
*Calculated assuming no exposure during the unsampled portion of the work shift.

Table V. Overall, they are much lower than the concentrations measured during the application in May. Consequently, residual air concentrations of diazinon measured in Section 3 over the weekend and during the work shift on Monday (Table VI) were also relatively low.

The results of area air sampling for diazinon in Section 4 of Plant 4 during the second site visit are presented in Tables VII and VIII. Two area air concentrations are presented for the four-hour application period of diazinon EC (Table VII), and two full-shift area air concentrations are presented for each of the three days that followed (Table VIII). Notable residual diazinon remained in the air of this section throughout these post-application days.

TABLE VI

Results of Area Air Sampling for Residual Diazinon
Plant 4, Section 3
Site Visit 2 [July 18 - 20, 1992]

Sampling Location	8-hour TWA Diazinon Concentration ($\mu g/m^3$)		
	July 18	July 19	July 20
Near door to break room	0.54	(0.20)	2.28
Bay A (North Wall)	2.29	1.31	1.98
Bay B (South Wall)	3.12	1.20	1.81

Temperature = 82°F and relative humidity = 59% at 1800 hours on July 18.
Temperature = 85°F and relative humidity = 50% at 1745 hours on July 19.
Temperature = 80°F and relative humidity = 77% at 1645 hours on July 20.

Note: The value in ( ) represents a concentration of diazinon between the minimum detectable concentration (0.08 $\mu g/m^3$) and the minimum quantifiable concentration (0.4 $\mu g/m^3$) based on 8-hour sampling durations, and should be considered a trace concentration.

$\mu g/m^3$: micrograms per cubic meter.
8-hour TWA: 8-hour time weighted average.

TABLE VII

Results of Area Air Sampling for Diazinon
[Coldfogging of Diazinon EC]
Plant 4, Section 4
Site Visit 2 [July 17, 1992]

Sampling Location	Sampling Period	Sampling Duration (minutes)	Diazinon Concentration (µg/m^3)
Bay A	2017 - 0042	265	4,150
Bay B	2017 - 0040	263	2,850

Temperature = 70°F and relative humidity = 91% at 0015 hour.

TABLE VIII

Results of Area Air Sampling for
Residual Diazinon
Plant 4, Section 4
Site Visit 2 [July 18 - 20, 1992]

Sampling Location	8-hour TWA Diazinon Concentration (µg/m^3) July 18	July 19	July 20
Bay A	173	65.9	29.2
Bay B	117	61.5	31.2

Temperature = 83°F and relative humidity = 65% at 1745 hours on July 18.
Temperature = 83°F and relative humidity = 55% at 1730 hours on July 19.
Temperature = 79°F and relative humidity = 77% at 1630 hours on July 20.

µg/m^3: micrograms per cubic meter.
8-hour TWA: 8-hour time-weighted average.

The results of area air sampling for chlorpyrifos at Plant 1 during the second site visit are presented in Tables IX and X. The sampling results presented in Table IX 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 operating [0300 - 0500], and (3) the period when mechanical ventilation was operating [0500 - 0730]. According to a representative of Green Circle Growers, the one exhaust fan that operated during the third sampling period produced a flow rate of 20,700 cubic feet per minute (CFM). Therefore, given that the cross-sectional area of Section B-2 is 1,440 square feet (ft^2), an average air velocity of 14.4 feet per minute 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 X. The concentrations presented in Table X are all well below the 200 µg/m³ occupational exposure limit of chlorpyrifos.

TABLE IX

Results of Area Air Sampling for Chlorpyrifos
[Coldfogging of Dursban® EC]
Plant 1, Section B-2
Site Visit 2 [July 17 -18, 1992]

Sampling Location	Sampling Period	Sampling Duration (minutes)	Chlorpyrifos Concentration (µg/m³)
Walkway	2200 - 0334	334	988
	0335 - 0528	113	133
	0530 - 0749	139	49
Fan side	2155 - 0328	333	1,620
	0331 - 0523	112	107
	0526 - 0739	133	75
Vent side	2154 - 0323	329	638
	0326 - 0517	111	99
	0520 - 0729	129	25
Section B-1	2157 - 0317	320	66
	0321 - 0511	110	14
	0515 - 0722	127	15
Section B-3	2202 - 0340	338	189
	0341 - 0536	115	40
	0539 - 0743	124	2

Temperature = 69°F and relative humidity = 93% at 0130 hours and 0500 hours.
µg/m³: micrograms per cubic meter.
2200 - 0300: Fogging application period.
0300 - 0500: Section closed (no fans).
0500 - 0730: One exhaust fan operating and vent open 2 inches.

TABLE X

Results of Area Air Sampling for Residual Chlorpyrifos
Plant 1, Section B-2
Site Visit 2 [July 18 - 20, 1992]

Sampling Location	8-hour TWA Chlorpyrifos Concentration (µg/m^3) July 18	July 19	July 20
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

Temperature = 86°F and relative humidity = 56% at 1500 hours on July 18.
Temperature = 86°F and relative humidity = 47% at 1345 hours on July 19.
Temperature = 79°F and relative humidity = 66% at 1540 hours on July 20.

Note: The value in ( ) represents a concentration of chlorpyrifos between the minimum detectable concentration (0.08 µg/m^3) and the minimum quantifiable concentration (0.2 µg/m^3) based on 8-hour sampling durations, and should be considered a trace concentration.

µg/m^3: micrograms per cubic meter.
8-hour TWA: 8-hour time weighted average.
ND: none detected.

Site Visit 3 [November 6-10, 1992]

Air Sampling

The results of area air sampling for diazinon in Section 3, Section 4, and two other locations of Plant 4 during the work shift prior to the pesticide applications in Sections 3 and 4 are presented in Table XI. Diazinon levels which exceeded trace amounts were measured in the break room and at the air sampling location located between the break room and Section 4. The

TABLE XI

Results of Area Air Sampling for
Diazinon [Pre-application]
Plant 4, Sections 3 and 4
Site Visit 3 [November 6, 1992]

Sampling Location	Sampling Period	Sampling Duration (minutes)	8-Hour TWA Diazinon Concentration (µg/m^3)
	Section 3		
Table C-21 (South Wall)	0716 - 1516	480	ND
Table C-7 (North Wall)	0720 - 1520	480	ND
Table A-6 (North Wall)	0723 - 1523	480	ND
Near Entrance (West Wall)	0721 - 1521	480	(0.4)
	Section 4		
Table B-20 (NW Wall)	0733 - 1533	480	(0.8)
Table B-12 (SW Wall)	0737 - 1537	480	(1.0)
Table A-21 (NE Wall)	0741 - 1541	480	(1.2)
Table A-12 (SE Wall)	0745 - 1545	480	(1.0)
	Other Locations		
Entrance to Section 5	0727 - 1527	480	8.0
Break room	0729 - 1529	480	2.1

Note: Values in ( ) represent concentrations of diazinon between the minimum detectable concentration (0.4 µg/m^3) and the minimum quantifiable concentration (1.2 µg/m^3) based on 8-hour sampling durations; they should be considered trace concentrations.

TABLE XIII

Results of Area Air Sampling for Residual Diazinon
Plant 4, Section 3
Site Visit 3 [November 7 - 10, 1992]

Sampling Location	8-Hour TWA Diazinon Concentration (µg/m³)			
	Nov. 7	Nov. 8	Nov. 9	Nov. 10
Table C-21 (South Wall)	52	21	12	12
Table C-7 (North Wall)	45	30	17	ND
Table A-6 (North Wall)	6.1	3.0	2.4	2.5
Near Entrance (West Wall)	[illegible]	4.2	[illegible]	[illegible]

Temperature = [illegible] and relative humidity = [illegible] at [illegible] hours on Nov. 8th.
Temperature = 70°F and relative humidity = 77% at 0920 hours on Nov. 9th.
Temperature = 71°F and relative humidity = 72% at 0840 hours on Nov. 10th.

µg/m³: micrograms per cubic meter.
8-hour TWA: 8-hour time weighted average.
ND: None detected.

Results of Personal and Area Air Sampling for Diazinon
[Spraying Application of Diazinon EC]
Plant 4, Section 3
Site Visit 3 [November 6, 1992]

Sampling Location	Sampling Period	Duration (minutes)	Diazinon Concentration (µg/m³) Actual	8-hour
On applicator	1627 - 1720	53	226	25.0
Table C-21 (South Wall)	1637 - 1715	38	239	18.9
Table C-7 (North Wall)	1639 - 1716	37	297	22.9
Table A-6 (North Wall)	1641 - 1719	38	ND	ND
Near Entrance (West Wall)	1640 - 1718	38	ND	ND

Temperature = 74°F and relative humidity = 74% at 1715 hours.
µg/m³: micrograms per cubic meter.
8-Hour TWA: 8-hour time weighted average.
ND: None detected.

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 XII. 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 XIII. Residual levels of diazinon remained in the air of this section throughout these post-application days. The results of 16 area air samples collected hourly at four locations during the four-hour coldfogging application of diazinon EC in Section 4 are shown in Table XIV. By comparison, diazinon concentrations measured during the coldfogging application in Section 4 far exceed the levels measured during the spraying application of the same pesticide in Section 3. Residual air concentrations of diazinon measured over the weekend and during the first two work shifts of the next week are shown in Table XV for Section 4 and in Table XVI for the break room and the air sampling location between the break room and Section 4. Full-shift area air concentrations measured at two locations in Section 4 on the day after the coldfogging application exceeded the 100 µg/m³ occupational exposure limit of diazinon, and substantial residual levels persisted in the air of this section throughout these post-application days.

TABLE XIV

Results of Area Air Sampling for Diazinon
[Coldfogging of Diazinon EC]
Plant 4, Section 4
Site Visit 3 [November 6, 1992]

Sampling Location	Sampling Period	Sampling Duration (minutes)	Diazinon Concentration (μg/m^3)
Table B-20 (NW Wall)	1900 - 2000	60	2,670
	2003 - 2104	61	3,930
	2105 - 2201	56	3,040
	2203 - 2300	57	2,630
Table B-12 (SW Wall)	1901 - 2003	62	1,530
	2007 - 2107	60	2,330
	2110 - 2205	55	2,360
	2207 - 2303	56	2,320
Table A-21 (NE Wall)	1903 - 2009	66	470
	2012 - 2112	60	967
	2114 - 2209	55	818
	2211 - 2307	56	982
Table A-12 (SE Wall)	1905 - 2013	68	529
	2016 - 2116	60	917
	2117 - 2213	56	946
	2215 - 2310	55	618

Temperature = 72°F and relative humidity = 70% at 2030 hours.
μg/m^3: micrograms per cubic meter.

TABLE XV

Results of Area Air Sampling for Residual Diazinon
Plant 4, Section 4
Site Visit 3 [November 7 - 10, 1992]

Sampling Location	8-Hour TWA Diazinon Concentration (µg/m^3)			
	Nov. 7	Nov. 8	Nov. 9	Nov. 10
Table B-20 (NW Wall)	250	67	59	40
Table B-12 (SW Wall)	230	60	51	38
Table A-21 (NE Wall)	81	27	30	23
Table A-12 (SE Wall)	70	27	20	19

Temperature = 73°F and relative humidity = 70% at 0850 hours on Nov. 7th.
Temperature = 76°F and relative humidity = 61% at 0900 hours on Nov. 8th.
Temperature = 70°F and relative humidity = 74% at 0915 hours on Nov. 9th.
Temperature = 70°F and relative humidity = 79% at 0835 hours on Nov. 10th.

µg/m^3: micrograms per cubic meter.
8-Hour TWA: 8-hour time weighted average.
ND: None detected.

TABLE XVI

Results of Area Air Sampling for Residual Diazinon
Plant 4, Other Locations
Site Visit 3 [November 7 - 10, 1992]

Sampling Location	8-Hour TWA Diazinon Concentration (µg/m^3)			
	Nov. 7	Nov. 8	Nov. 9	Nov. 10
Entrance to Section 5	9.9	6.1	10	5.2
Break room	(0.8)	(0.8)	(1.2)	(1.4)

Temperature = 72°F and relative humidity = 35% at 0845 hours on Nov. 7th.
Temperature = 75°F and relative humidity = 36% at 0910 hours on Nov. 8th.
Temperature = 69°F and relative humidity = 31% at 0910 hours on Nov. 9th.
Temperature = 71°F and relative humidity = 42% at 0830 hours on Nov. 10th.

Note: Values in ( ) represent concentrations of diazinon between the minimum detectable concentration (0.4 µg/m^3) and the minimum quantifiable concentration (1.7 µg/m^3) based on 8-hour sampling durations; they should be considered trace concentrations.

µg/m^3: micrograms per cubic meter.
8-Hour TWA: 8-hour time weighted average.
ND: None detected.

Glove Monitor Sampling

The results of glove monitor sampling for potential skin exposure during the work shift just prior to the spraying and coldfogging applications of diazinon and during the first and second work days of the following work week are presented in Tables XVII, XVIII, and XIX. Glove monitoring results for the pre-application work shift (Table XVII) show that diazinon concentrations exceeding trace amounts were measured on greenhouse laborers B and D. Laborer B worked this shift in Section 3 cleaning plants. Laborer D worked this shift in Section 3 and in the wholesale area loading and unloading plastic baskets of plants. Only one of the glove monitors worn by the greenhouse laborers who also wore latex gloves was found to have detectable concentrations of diazinon. Glove monitoring results from the first work shift after the pesticide applications in Sections 3 and 4 (Table XVIII) show that diazinon concentrations were measured on the glove monitors worn by workers A (the supervisor), B, C, and D. One of the glove

TABLE XVII
Results of Glove Monitor Sampling for Diazinon
Plant 4
Site Visit 3 [November 6, 1992]

Greenhouse Worker	Sampling Period	Sampling Duration (minutes)	Diazinon Concentration (µg/Hour) Left Hand	Diazinon Concentration (µg/Hour) Right Hand
	Sampling Glove Monitors Only			
A	0800 - 1030	150	(2)	(2)
	1045 - 1310	145	(2)	(2)
	1350 - 1630	160	(3)	(2)
B	0800 - 1030	150	35	44
	1045 - 1310	145	28	41
	1350 - 1630	160	(2)	ND
C	0800 - 1030	150	(1)	ND
	1045 - 1310	145	(2)	(1)
	1350 - 1630	160	(2)	ND
D	0800 - 1030	150	5.6	5.6
	1045 - 1310	145	(2)	(3)
	1350 - 1630	160	13	4.1
E	0800 - 1030	150	(2)	(2)
	1045 - 1310	145	(2)	(2)
	1350 - 1630	160	(3)	(3)
	Sampling Glove Monitors under Latex Gloves			
F	0800 - 1030	150	ND	ND
	1045 - 1312	147	ND	ND
	1350 - 1630	160	ND	ND
G	0800 - 1030	150	ND	ND
	1045 - 1312	147	ND	ND
	1350 - 1630	160	ND	ND
H	0800 - 1030	150	(1)	ND
	1045 - 1312	147	ND	ND
	1350 - 1630	160	ND	ND
I	0800 - 1030	150	ND	ND
	1045 - 1312	147	ND	ND
	1350 - 1630	160	ND	ND
J	0800 - 1030	150	ND	ND
	1045 - 1312	147	ND	ND
	1350 - 1612	142	ND	ND

Note: Values in ( ) represent concentrations of diazinon between the minimum detectable concentration (0.8 µg/hour) and the minimum quantifiable concentration

TABLE XVIII

Results of Glove Monitor Sampling for Diazinon
Plant 4
Site Visit 3 [November 9, 1992]

Greenhouse Worker	Sampling		Diazinon Concentration (µg/Hour)	
	Period	Duration (minutes)	Left Hand	Right Hand
	Sampling Glove Monitors Only			
A	0800 - 1030	150	5.6	8.4
	1050 - 1310	140	6.1	11
	1350 - 1630	160	(4)	5.2
B	0800 - 1030	150	32	76
	1045 - 1310	145	50	69
	1350 - 1630	160	35	96
C	0800 - 1030	150	4.4	4.0
	1045 - 1310	145	(2)	(2)
	1350 - 1630	160	7.0	13
D	0800 - 1030	150	37	40
	1045 - 1310	145	24	42
	1350 - 1630	160	17	26
E	0800 - 1030	150	ND	ND
	1045 - 1235	110	ND	ND
	1310 - 1630	200	ND	ND
	Sampling Glove Monitors under Latex Gloves			
F	0800 - 1030	150	ND	ND
	1045 - 1310	145	ND	ND
	1345 - 1630	165	ND	ND
G	0800 - 1030	150	ND	ND
	1045 - 1310	145	ND	ND
	1345 - 1630	165	ND	ND
H	0800 - 1030	150	ND	ND
	1045 - 1310	145	ND	ND
	1345 - 1630	165	(1)	ND
I	0800 - 1030	150	ND	ND
	1045 - 1310	145	ND	ND
	1345 - 1630	165	ND	ND
J	0800 - 1030	150	ND	ND
	1045 - 1310	145	ND	ND
	1345 - 1630	165	ND	ND

Note: Values in ( ) represent concentrations of diazinon between the minimum detectable concentration (0.8 µg/hour) and the minimum quantifiable concentration (3.2 µg/hour) based on 2.5-hour sampling durations; they should be considered trace monitors worn by the greenhouse laborers who also wore latex gloves was found to have detectable concentrations of diazinon. Laborer B did the same work this shift as on the pre-application testing day, cleaning plants in Section 4. Laborer C worked this shift in Section 4 cleaning plants. Laborer D was again assigned to load and unload plants, but in Section 4 and in the wholesale area. Laborer E was also asssigned to load and unload plants, but spent this entire work shift in greenhouse sections that had not been treated with diazinon. Glove monitor sampling results from the second work shift after the pesticide applications in Sections 3 and 4 (Table XIX) show that diazinon concentrations were measured on glove monitors of workers A (the supervisor), B, C, E, and F. The job locations and tasks of laborers B and C did not change from the previous day. Laborer E loaded and unloaded plants in Sections 3 and 4 and the wholesale area, and laborer F worked the vast majority of this work shift planting off-shore material in the soil barn. Two of the glove monitors worn by the greenhouse laborers who also wore latex gloves were found to have detectable concentrations of diazinon, and one glove monitor had a quantifiable concentration.

TABLE XIX

Results of Glove Monitor Sampling for Diazinon
Plant 4
Site Visit 3 [November 10, 1992]

Greenhouse Worker	Sampling		Diazinon Concentration (µg/Hour)	
	Period	Duration (minutes)	Left Hand	Right Hand
	Sampling Glove Monitors Only			
A	0800 - 1030	150	6.0	7.2
	1045 - 1135	50	18	15
	1135 - 1310	95	6.9	8.8
	1350 - 1618	148	ND	ND
B	0800 - 1030	150	44	76
	1045 - 1310	145	5.8	21
	1350 - 1630	160	8.1	148
C	0800 - 1030	150	(1)	(1)
	1045 - 1310	145	32	24
	1350 - 1630	160	(3)	(1)
D	0800 - 1015	135	(2)	(2)
	1030 - 1310	160	(2)	ND
	1350 - 1630	160	(1)	(2)
E	0800 - 1030	150	16	18
	1045 - 1310	145	28	20
	1350 - 1630	160	(1)	20
	Sampling Glove Monitors under Latex Gloves			
F	0800 - 1030	150	ND	ND
	1045 - 1315	150	ND	ND
	1350 - 1630	165	3.5	ND
G	0800 - 1030	150	ND	ND
	1045 - 1315	150	ND	ND
	1350 - 1630	160	ND	ND
H	0800 - 1030	150	ND	(1)
	1045 - 1315	150	ND	ND
	1350 - 1625	155	(1)	ND
I	0800 - 1030	150	ND	ND
	1045 - 1315	150	ND	ND
	1350 - 1630	160	ND	ND
J	0800 - 1030	150	ND	ND
	1045 - 1315	150	ND	ND
	1350 - 1630	160	ND	ND

Note: Values in ( ) represent concentrations of diazinon between the minimum detectable concentration (1.2 µg/hour) and the minimum quantifiable concentration (4.0 µg/hour) based on 2.5-hour sampling durations; they should be considered trace

Site Visit 4 [December 16, 1992]

No residual pesticides were detected when leaf sections of off-shore plant materials (philodendron and golden pothos leaves) were screened for 29 organophosphate and 10 carbamate analytes.

Similarily, neither aldicarb sulfone nor oxamyl was detected on any of the eight gloves worn by four greenhouse laborers who handled the off-shore golden pothos leaves.

Medical

Confidential Medical Interviews

Of the 47 greenhouse laborers employed at the end of April 1992, 15 (32%) had worked for more than two years, and 20 (43%) had worked for five months or less. Except for a grower and grower assistant who had been employed for approximately eight years, the remaining employees had been with the company from six months to four years.
Nine (47%) of the nineteen interviewed employees reported symptoms (excluding skin rash) that they had experienced in the previous month (Table XX). The most frequently reported symptoms were eye, nose, or throat irritation; and headache, lightheadedness, tiredness, or problems with memory or concentration. Six (32%) of the interviewed employees reported problems with skin rash in the previous month.

TABLE XX

Symptoms Reported by 19 Employees
Plant 4
May 13, 1992

Symptoms experienced in the previous month	Number (%) with symptoms	
	Chemical applicators (n = 5)	Others (n = 14)
Headache, lightheadedness, tiredness, or problems with memory or concentration	1 (20)	4 (29)
Eye, nose, or throat irritation (including cough)	2 (40)	5 (36)
Increased tears, secretions from the nose or lungs, or sweating	1 (20)	3 (21)
Blurred vision	0	3 (21)
Chest tightness, wheezing, or shortness of breath	0	2 (14)
Heart palpitations	0	2 (14)
Nausea, abdominal discomfort, or diarrhea	0	4 (29)
Muscle tremors or fasciculations	1 (20)	3 (21)
Any of the above symptoms	2 (40)	7 (50)
Skin rash	1 (20)	5 (36)

Four (21%) of the 19 employees interviewed reported allergy to plants. Seventeen employees were examined for skin lesions on the hands or forearms. One of the five whose job tasks included chemical application, and three of the twelve who did not apply chemicals, had skin abnormalities, which included scaling, erythema (redness), hyperpigmentation, or a maculopapular (small bumpy) rash.

In addition to the symptoms experienced in the previous month, some employees reported earlier episodes of acute symptoms associated with specific exposures. For applicators, the symptoms occurred during application of oxamyl (Vydate® L insecticide/nematicide) without a respirator or from uncontrolled spray when the spray nozzle became disconnected from the hose. For other employees, the symptoms occurred on entering the greenhouse after oxamyl was applied or after smoke bombs were released. The acute symptoms related to oxamyl exposure included chest pain, muscle twitching, vomiting, diarrhea, and abdominal cramps. The symptoms related to the smoke bomb included cough, chest tightness, and shortness of breath. These episodes were not reported to management.

Of the 14 employees whose job tasks did not include chemical application, four reported that chemical applications had taken place while they were still in the section, five reported that they had entered sections when plants were still wet, and four reported that they have had skin contact with chemicals while handling plants. These employees did not necessarily know which chemicals had been applied, and most were unaware of the concept of "reentry time."

Other concerns about chemical exposures included the potential for exposure when walking through Section 3 to go to the lunchroom, bathrooms, and time clock; potential contamination of the lunchroom; entering sections without protective equipment to open vents before the reentry time; drenching or spraying without use of protective head covering; lack of standardized procedures for disposing contaminated protective clothing; and chemical odors emanating from open chemical containers without lids.

Disposal practices for contaminated protective clothing were reported to vary. Some of the contaminated clothes were folded inside out, some were wrapped in plastic bags, and some were neither specially folded nor wrapped with uncontaminated material. Contaminated clothes were placed directly either in a trash can or in the dumpster.

Eleven of the 19 interviewed employees reported that they had received information on pesticides, but most could not give interviewers information about the potential health effects of overexposure. A pamphlet on pesticides was reported to have been distributed within the previous year.

Most of the interviewed employees reported symptoms related to heat exposure (Table XXI). In the summer, greenhouse temperatures were reported to be consistently higher than 105°F, and temperatures occasionally reached 115°F when the vents were closed. The highest temperature reported was 130°F when the vents were closed. None of the interviewed employees reported training on heat stress. Employees are allowed to leave their sections if they have symptoms consistent with heat stress, but no other measures are taken to evaluate or treat heat stress.

TABLE XXI
Symptoms Related to Heat
Among 19 Employees
Plant 4
May 13, 1992

Symptoms	Number
Feel hot	11
Increased sweating	10
Increased thirst	9
Feel weak	6
Short of breath	6
Heart palpitation	5
Dizziness	3
Blurred vision	2
Nausea	1
Headache, tiredness, or decreased appetite	2
Any symptoms*	14

Medical Monitoring Program for Chemical Exposure

The employer's medical monitoring program for chemical exposure consists of laboratory analyses of blood and urine specimens collected every six months from employees with potential for

TABLE XXII

Pseudocholinesterase Results of Current Employees under Medical Monitoring
Plant 4
May 13, 1992

Employee	Time from date of hire to date of first test	Number of tests over number of years	Range of values[a] (U/ml)	Lowest value as percent of highest value	Lowest value as percent of earliest value[b]	Greatest percent decrease between two consecutive values
A	7 years	12/3.7	3.7 - 6.1	60.7	74.0	32.7
B	7 months	2/0.3	3.0 - 4.7	63.8	78.9	21.1
C	2 months	18/5.7	4.7 - 6.6	71.2	79.7	23.0
D	10 months	6/1.9	4.4 - 5.5	80.0	88.0	17.0
E	7 months	7/6.3	3.2 - 3.9	82.1	100.0	—
F	4 years	6/1.9	5.5 - 6.1	90.2	93.2	9.8

[a]Reference range reported by the laboratory is 2.7 to 7.4 units (U)/ml.
[b]No test results corresponding to time of first employment were available. Therefore, percent of actual baseline could not be calculated.

exposure (growers, assistant growers, and grower's helpers). The tests include a complete blood count, serum chemistry panel, urinalysis, and P-ChE activity. Management personnel review the laboratory reports and interpret the results by comparing them with reference ranges provided on the reports. Results outside the reference range are referred to a local occupational physician for review. Management informs employees of their results and whether the results are within the reference ranges. Six current Plant 4 employees have been medically monitored, and their P-ChE results are shown in Table XXII. The date of the earliest P-ChE result for each employee was months to years after date of hire, so these results might not have been actual baselines. Therefore, decreases in P-ChE were calculated using the highest, as well as earliest, P-ChE as "baseline." Two of the monitored employees had evidence of greater than 30% decreases in P-ChE activity, and the decrease in another employee's P-ChE activity approached 30%, indicating possible overexposure. Using the laboratory's reference range, however, management had considered these results normal.

Laboratory reports for 15 employees who had been medically monitored during work at the other Green Circle Grower plants were also reviewed. Using the highest P-ChE as "baseline," seven of the fifteen (47%) had greater than 30% decreases in P-ChE activity (57.3-69.6% of baseline), and five (33%) had decreases that approached 30% (70.5%-73.0% of baseline).

Review of the OSHA Form 200 Logs

A review of the OSHA Form 200 logs showed that most of the reported incidents were acute injuries. Three cases of chemical vapor inhalation were reported in the first quarter of 1992. The exposures appeared to be related to one incident, since the reports occurred on the same day. This incident did not appear to be the same as any of those reported during the confidential employee interviews conducted by NIOSH investigators. Thirteen episodes of skin rash were reported in 1991, and four in 1990. One episode of eye exposure to insecticide was reported in 1990.

DISCUSSION AND CONCLUSIONS

Industrial Hygiene

Crystalline Silica

Crushed limestone, a potential source of crystalline silica, is added to the soil used for planting leaf sections to maintain acceptable pH levels. The limestone is added directly from the hopper in which it is delivered from the supplier. The hopper was positioned in front of a 48-inch diameter exhaust fan which removed fugitive dust emissions from the soil barn to the outside. Workers reported that exposure to airborne limestone dust occurred every six months or so when a "puff" of dust was released from the top of the hopper if the operator had not been vigilant enough to keep the material flowing smoothly from the hopper. The low content (1.8%) of quartz found in a single sample of crushed limestone, and infrequent exposures of soil barn workers to the airborne dust suggest that there is virtually no health risk associated with the crushed limestone.

Asbestos Cement Sheets

Although broken and cracked asbestos cement sheets were seen in Sections 3 and 4 of Plant 4, the asbestos is considered nonfriable. Inhalation exposure is unlikely as long as the asbestos cement sheets remain intact. However, inhalation exposure may be possible if the sheets break during handling or are damaged in other ways.

Air Sampling

Area air sampling conducted during work shifts before pesticide applications at Plant 4 resulted in the measurement of either non-detectable or trace concentrations of diazinon (Tables IV and XI), with the exception of two concentrations (8.0 and 2.1 $\mu g/m^3$) measured during the third site visit (Table XI). The grower's pesticide application records showed that a coldfogging application of diazinon had been made in Section 5 four days prior to area air sampling at locations near the entrance to Section 5 and in the break room. The application on the morning of November 2, 1992, involved one fogger; one liter (approximately 2 pints) of diazinon EC was added to 18 liters of water contained in the fogger's reservoir. Area air concentrations of diazinon measured on November 6, 1992, near the entrance to Section 5 and in the break room were most likely residual levels remaining from the coldfogging application which occurred earlier that same work week.

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.[28] 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."[28]

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."[28] 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."[28]

During the spraying application of diazinon monitored during the first site visit, 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. It was learned from a discussion with the applicator 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 Green Circle Growers facilities be implemented in accordance with OSHA regulations and NIOSH recommendations. In addition, it was recommended that respirator cartridges be replaced 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."[29] Wearing a hooded disposable protective suit during pesticide spraying was also recommended. These recommendations were implemented by Green Circle Growers prior to the second NIOSH site visit. During the spraying applications of diazinon monitored during the second and third site visits, 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 Tables V and XII.

When a microencapsulated formulation of diazinon (Knox-out®) was sprayed during the first site visit, PBZ air sampling of the applicator resulted in a diazinon concentration of 116 $\mu g/m^3$ during the 74-minute application period; this represents an 8-hour TWA concentration of 18 $\mu g/m^3$ (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 13 $\mu g/m^3$ to 21 $\mu g/m^3$ (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 received essentially the same inhalation dose of diazinon as the applicator, who was exposed to a high concentration over a short period (74 minutes), while the laborers were exposed to low concentrations over 8 hours. The diazinon air concentration immediately after completion of the application is unknown. Based on these sampling results, however, an unprotected worker entering the treated section immediately after the application was completed may be at risk for inhalation exposure. During the second site visit, air sampling was conducted during the same operation, with the exception that a more dilute solution of Knox-out® was used. Air concentrations of diazinon measured during this application (Table V) and for three consecutive days after the application (Table VI) were much lower than those measured during the initial site visit. Operation of air-circulating fans in Section 3 after each application probably influenced the levels of residual diazinon measured, but the extent of this influence is unknown.

During the 53-minute spraying application of an EC formulation of diazinon (Clean Crop AG500), 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 Bay C of the same section begun 15 hours after completion of the spraying application measured diazinon concentrations of 45 $\mu g/m^3$ and 52 $\mu g/m^3$ (Table XIII). This represents a considerably higher residual air concentration of diazinon after application of the EC formulation compared to measurements made after application of the microencapsulated formulation. During the first site visit, the ratio of diazinon to water mixed for the application of the microencapsulated formulation (Knox-out®) was 0.17% (6 pints of 23% diazinon in 800 pints of water). During the third site visit, an equivalent ratio of diazinon to water (0.18%) was mixed for the application of the EC formulation (Clean Crop AG500) (3 pints of 48% diazinon in 800 pints of water). Therefore, the difference in residual air concentrations between these two post-application periods cannot be attributed to a difference in the concentration of diazinon mixed initially in the holding tank of the application equipment.

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."[(28)] 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/m^3 is reached*."[(30)] 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; or (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."[(28)]

Area air concentrations of diazinon measured during coldfogging operations in Section 4 of Plant 4 (Tables VII and XIV) were substantially higher than area air concentrations measured during spraying applications in Section 3 (Tables III, V and XII). Consequently, area air sampling in Section 4 began almost 10 hours after completion of the coldfogging applications measured 8-hour TWA concentrations which exceeded the exposure limit of diazinon (Tables VIII and XV). The coldfogging of diazinon in Bays C and D of Section 4 on the night of July 18 could have contributed to the diazinon concentrations measured in Bays A and B on July 19 and 20, but the extent of this contribution is unknown. Substantial 8-hour TWA air concentrations were measured in Section 4 during the work shifts monitored after both coldfogging applications. 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 post-application levels of residual diazinon measured. Overall, these sampling 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 1 during five hours of coldfogging represents an 8-hour TWA of 400 $\mu g/m^3$, which exceeds the exposure limit for chlorpyrifos. The area air concentrations of chlorpyrifos measured in Section B-2 of Plant 1 during the period after the coldfogging when the exhaust fan was operating (Table IX) and during the full-shift 8-hour sampling period immediately after the coldfogging (Table X) were all less than its exposure limit. The exhaust fan was turned on two hours after coldfogging was completed and operated for 2.5 hours; approximately ten air changes were completed during this period. These sampling results suggest that the EPA restricted-entry intervals are sufficient after coldfogging operations in greenhouses with mechanical exhaust ventilation systems.

During the third site visit at Plant 4, a night watchman was observed entering greenhouse sections for brief periods during coldfogging applications, as well as shortly after spraying applications. The watchman wore a NIOSH-approved half-mask respirator with pesticide cartridges, work clothes, and work boots. Section 170.112 (c) of the EPA Worker Protection Standard addresses the requirements by which a worker may enter a treated area during a restricted-entry interval for short-term activities not to exceed 1 hour in any 24-hour period. The standard requires that the personal protective equipment worn when entering a treated area during a restricted-entry interval include, but not be limited to "coveralls, chemical-resistant suits, chemical-resistant gloves, chemical-resistant footwear, respiratory protection devices, chemical-resistant aprons, chemical-resistant headgear, and protective eyewear. Long-sleeved shirts, short-sleeved shirts, long pants, short pants, shoes, socks, and other items of work clothing are not considered personal protective equipment for the purposes of this section."[28]

Glove Monitor Sampling

Wearing industrial grade latex or vinyl gloves when working with plants that have been treated with pesticides is optional at Green Circle Growers, and very few greenhouse workers were observed wearing gloves. The EPA Worker Protection Standard[28] and the EPA Labeling Requirements for Pesticides and Devices[30] require the wearing of chemical-resistant gloves by pesticide handlers (applicators) and workers who enter treated areas during restricted-entry intervals. Section 170.150 of the Worker Protection Standard addresses worker skin exposures after expiration of restricted-entry intervals and does not require the wearing of hand protection, but it does require that "if any worker on an agricultural establishment performs any activity in an area where, within the last 30 days, a pesticide has been applied or a restricted-entry interval has been in effect and contacts anything that has been treated with the pesticide, including, but not limited to, soil, water, or surfaces of plants, the agricultural employer shall provide, in accordance with this section, a decontamination site for washing off pesticide residues."[28]

Glove monitor sampling resulted in the measurement of diazinon concentrations on the gloves of two laborers who worked in Section 3 during the work shift just before pesticide application on November 6, 1992. The grower's pesticide application records showed that the section's last application of diazinon, a coldfogging application of the EC formulation, had occurred 48 days before, on September 19, 1992. The grower stated that the majority of plants in the section on that date were still in the section on November 6. These results suggest that plants treated with diazinon can be sources of skin exposure for many days after an application. Analysis of the sampling glove monitors worn by employees who handled treated plants on the first two work days after diazinon applications in Sections 3 and 4 also showed measurable concentrations of diazinon. When worn under latex gloves, only five (6%) of the sampling glove monitors showed detectable quantities of diazinon. These results suggest that workers handling plants treated with diazinon are protected from hand exposure by wearing industrial-grade latex gloves.

Off-shore leaf materials are not purchased directly from farmers in Costa Rica, but from brokers in the United States. Therefore, Green Circle Growers has been unable to obtain information about off-shore pesticide applications. A broker representative stated in a correspondence with the company that "many [farmers] consider this information proprietary and would rather not give out specific data." The reasons for wanting to protect such information were not given. The broker also stated that while "the specific chemicals applied are normally dependent upon local availability of chemicals," the pesticides used are known to include aldicarb, dienochlor, fenamiphos, fenbutatin-oxide, fluvalinate, metalaxyl, and oxamyl. Based upon available published reports concerning these pesticides, skin contact is a potential route of exposure for aldicarb(31) and oxamyl(32, 33) (carbamate insecticides), fenamiphos(34) (an organophosphate nematicide), and fluvalinate.(35-38) When samples of off-shore leaf materials were analyzed for 29 organophosphate and 10 carbamate pesticides, no residual pesticides were detected. Similarily, neither aldicarb sulfone nor oxamyl was detected on any of eight sampling glove monitors worn by greenhouse laborers while handling off-shore leaves. However, these sampling data are very limited, and skin exposure to residual pesticides on off-shore leaf material cannot be discounted as a potential health risk for soil barn workers.

Medical

Greenhouse Chemicals

The symptoms reported by the interviewed employees are nonspecific and could be caused by any of a number of factors, including, but not limited to, pesticide exposure. Many of the reported symptoms (headache; tiredness; eye, nose, or throat irritation; nasal congestion; chest tightness, wheezing, or shortness of breath; and nausea, abdominal discomfort, or diarrhea) are commonly related to viral infections, such as colds and influenza. When these symptoms occur in characteristic patterns, however, they may indicate health effects related to pesticide exposure. For example, organophosphate and carbamate insecticides can produce characteristic symptoms, such as increased tears and saliva, that are unusual in respiratory infections. Reliable diagnoses can be made only after appropriate medical evaluation. RBC-ChE and P-ChE activity are sometimes useful for diagnosing health effects of exposure to ChE-inhibiting insecticides.

P-ChE activity returns to baseline earlier than that of RBC-ChE. Therefore, the highest P-ChE results in Green Circle Grower pesticide applicators may reflect actual baselines. For the same reason, unless blood specimens were obtained soon after exposure, decreases in P-ChE activity would be difficult to document. The latter is especially true for carbamate exposures, since the effect of carbamates on ChE is short acting. Therefore, periodic P-ChE testing might not have detected actual overexposures. Some of the P-ChE results and many of the symptoms reported, however, suggest that employees of Green Circle Growers were probably overexposed to

ChE-inhibiting insecticides. The same practices that resulted in overexposure to ChE-inhibiting insecticides could also have resulted in overexposure to other greenhouse chemicals. Although P-ChE activity was not monitored in greenhouse laborers, the symptoms they reported indicate that they also might have been overexposed to greenhouse chemicals. Possible explanations for exposure to non-applicators include walking through or near sections during application, early reentry into the application area, persistence of chemicals in greenhouse air well after application (a possibility confirmed by the post-application area air sampling results), and skin contact with residues on plant leaves and in the soil. In addition, high indoor temperatures and skin lesions may increase the skin absorption of certain greenhouse chemicals such as organophosphate insecticides.(21)

Dermatitis

Skin rashes in nursery workers, gardeners, and florists have been attributed to handling plants such as chrysanthemums, dieffenbachia, English ivy, philodendron, begonia, African violet, hyacinth, and poinsettia.(39, 40) These plants are recognized sources of skin irritation and allergies at Green Circle Growers. Some skin rashes, however, may be related to greenhouse chemicals, either to active ingredients or to additives such as organic solvents and emulsifiers. Fungicides such as benomyl (benlate) can cause allergic contact dermatitis,(41) and solvents are well known causes of irritant contact dermatitis.(42) In addition, acidic or alkaline formulations can cause irritant contact dermatitis.(41) These possibilities should be considered in the evaluation of skin lesions.

Heat Exposure

The reported temperatures of greater than 100°F and symptoms consistent with heat stress suggest that employees of Green Circle Growers are at risk for heat stress. Although most interviewed employees reported minor symptoms (feeling hot, increased sweating, increased thirst), symptoms indicating potentially more serious problems (heart palpitations, shortness of breath) were also reported. The frequency and severity of heat stress symptoms might have been reduced because of acclimatization to heat and the work practice of leaving hot environments whenever symptoms are noticeable.

Hazard Communication

Section 1910.1200 (g)(1) of the OSHA hazard communication standard requires that an employer have an MSDS for each hazardous chemical used, but section 1910.1200 (g)(2) requires only that each MSDS be in English. Although OSHA regulations do not require translations into other languages, hazard communication would probably be ineffective unless translated information and materials are made available to employees who do not understand English. The confidential employee interviews revealed that employees (English-speaking, as well as Spanish-speaking) did not have adequate knowledge about greenhouse chemicals and heat. In addition, employees were not regularly reporting episodes that affected their health.

RECOMMENDATIONS

Crystalline Silica

While there was virtually no health risk associated with the use of crushed limestone in the soil barn, training of new operators should emphasize the importance of keeping the material flowing smoothly from the hopper to avoid unnecessary releases of dust into the work area.

Asbestos Cement Sheets

Whenever asbestos cement sheets are moved or replaced with non-asbestos containing materials, precautions should be taken to ensure that inhalation exposures do not occur from breakage during handling. Before moving an asbestos cement sheet, it should be wrapped completely in plastic so that any fibers that might be released will be contained within the wrapping if breakage occurs.

Greenhouse Chemicals

PBZ air sampling of the applicator during two of the three spraying applications of diazinon resulted in the measurement of high concentrations during brief application periods of 74 and 53 minutes. Because of the risk of a decrease in RBC-ChE activity associated with excessive inhalation and skin exposures to organophosphate and carbamate pesticides, each pesticide applicator at Green Circle Growers 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 Green Circle Growers Plant 4 were at risk of inhalation exposure to residual pesticide concentrations. The results of area air sampling during the first site visit showed that greenhouse laborers were at risk of inhalation exposure to low concentrations of diazinon on the day immediately following a spraying application of a microencapsulated formulation. The results of area air sampling during the third site visit showed that diazinon concentrations measured following a spraying application on a Friday evening of an EC formulation declined over the weekend to low levels on Monday and Tuesday. However, post-application air concentrations measured when greenhouse laborers worked in treated sections did not exceed the exposure limit for diazinon. 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, growers 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. 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 would be exposed either in the section being treated or in adjacent sections, and (2) on each day following a coldfogging application at Plant 4. Mechanical exhaust ventilation operated immediately after the monitored coldfogging application at Plant 1 reduced air concentrations of chlorpyrifos to well below its exposure limit in a short period. However, 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 4. Because substantial residual pesticide concentrations remained in a greenhouse section with passive ventilation after coldfogging applications, coldfogging should be discontinued at Plant 4 until exhaust fans and sources of outside supply air are installed.

In addition to inhalation exposures, the results of glove monitor sampling showed that diazinon concentrations were measured on glove monitors worn by greenhouse laborers who handled plants treated with this insecticide. Skin exposure to diazinon was measured on two laborers who handled plants which had been treated 48 days earlier. Therefore, all workers should be required to wear industrial-grade latex gloves while handling pesticide-treated plants, regardless of when the application occurred. Likewise, soil-barn employees should also be required to wear gloves when handling off-shore leaf material. Vinyl gloves should also be available for use by those workers who have latex-allergy.[43, 44] In addition to hand contact, some laborers were observed reaching across tables to clean plants, which could have potentially resulted in skin exposure of the arms and upper body. Workers who frequently reach across treated plants should be required to wear aprons and disposable sleeve protectors. Disposable gloves and sleeve protectors, should be removed and discarded immediately before a worker leaves a section or the soil barn for a break or lunch period, or at the end of a work shift. A container lined with a plastic bag that is designated only for the disposal of used gloves and sleeve protectors should be available in each section and in the soil barn. The bags should be removed from their containers after each shift, sealed, and placed in a trash container for subsequent disposal in a landfill. Immediately after removing disposable gloves and sleeve protectors, workers should thoroughly wash their hands and arms with soap and water. Bar soap and powered soap should not be used, but liquid soap should be available from a dispenser. To further reduce the possibility of cross-contamination, foot pedals should be installed for controlling the water flow rate during washing.

To determine the potential risks associated with handling imported leaf material, information regarding the pesticide applications associated with each shipment of off-shore leaf material should be obtained and should include (1) names of the pesticides applied, (2) application rates, and (3) dates of applications.

Medical Monitoring Program

Without the supervision of a medical practitioner, a medical monitoring program cannot effectively protect employees. Results of the medical tests should be reviewed and interpreted only by medically trained professionals who have knowledge of the exposures and the potential for adverse health effects, in addition to knowledge of medical conditions that may affect an individual's results. Therefore, the medical monitoring program should be supervised by a physician, preferably an occupational medicine specialist. Such specialists are also trained to make appropriate recommendations to prevent further cases of occupational disease in the workplace. Furthermore, individual test results should be reported to the employee by an appropriate medical professional. Review of employee medical test results by management is inappropriate from the standpoint of an employee's right to privacy of personal health information. Finally, blood or urine tests, such as the blood counts, serum chemistries, and urinalyses provided by Green Circle Growers, are not relevant to the routine monitoring of workers for exposures to pesticides or other chemicals used at Green Circle Growers. Such tests should be ordered only on an individual basis at the discretion of a responsible physician.

RBC-ChE activity, as well as that of P-ChE, should be measured for all employees (e.g., pesticide applicators) potentially exposed to organophosphates for determination of a pre-exposure baseline. Greenhouse laborers should be included in the medical monitoring program, at least for baseline measurements, if they are at risk for exposure.

Pre-exposure baseline for RBC-ChE activity is defined by NIOSH as the mean of two RBC-ChE determinations, each of which is derived from a separate sample of blood taken at least one day apart after a period of at least 60 days without known exposure to any ChE-inhibiting compounds. If the ChE determinations produce values differing by more than 15%, additional determinations on new samples should be performed until successive tests do not differ by more than 15%.[22] Because RBC-ChE may not return to baseline within 60 days, determination of true pre-exposure values for currently exposed employees may not be possible.

Measurements of periodic RBC-ChE activity should be made available as frequently as once a week for employees who are potentially exposed to ChE-inhibiting insecticides. The testing frequency may be initially increased to as often as every day, or, after three determinations, may be decreased to as infrequently as every eight weeks. The frequency should be based on the decision of a responsible medical practitioner after consideration of the following for each employee: (1) the toxicity of the pesticides to which the employee may be exposed; (2) the potential duration and concentration of the pesticide exposure; (3) the state of health of the employee; and (4) the results of previous RBC-ChE determinations.

Aggregate data, as well as any individual results suggesting pesticide overexposure, should be reviewed by the supervisory physician. Group results should be reported to management and used to evaluate and improve exposure control measures. Management must be notified of cases of pesticide poisoning, which must be recorded on the OSHA Form 200. However, specific medical details should be considered confidential information and not be divulged without written consent from the affected individual.

Acutely overexposed employees or employees exhibiting symptoms and signs of overexposure should be referred to a medical practitioner for examination, including tests for RBC-ChE and P-ChE if exposures were to ChE-inhibiting insecticides. P-ChE activity can be useful in monitoring recovery.

All employees, including greenhouse labor, should be informed about greenhouse chemicals before beginning work in the greenhouse. The information should include, identification by name (including synonyms), characteristics (such as smell and appearance), and physical properties; hazards and toxicity; signs and symptoms of overexposure; precautions for safe handling; emergency first-aid treatment for overexposure; and emergency escape routes. Employees should also be trained in the practice of, and reasons for, work procedures and personal hygiene. All training should be conducted on a pre-assignment basis, and retraining should be conducted semi-annually or whenever necessitated by changes in equipment, processes, materials, and employee work assignments. Employees who do not understand English should receive training in their primary language. Translations of MSDSs and other written materials should be made available for employees who are not literate in English.

Heat Exposure

A heat stress evaluation involving work-rate estimations and WBGT measurements should be conducted when weather conditions present a potential for the development of heat stress. When feasible, engineering controls should be implemented to reduce exposure to heat. Recommendations for engineering controls, as well as other methods of controlling heat exposure are described in the NIOSH Criteria for a Recommended Standard: Occupational Exposure to Hot Environments (see Figure 1 and Figure 2).[26]

Methods for controlling heat stress include reducing the physical demands of the work, reducing duration of each heat exposure, and cooling the air. Radiant heat exposure (measured by the globe thermometer) can be decreased by heat reflective screens or clothing. Convective heat loads greater than 95°F (dry bulb thermometer) can be decreased by cooling the air and reducing air flow across skin. When convective heat loads are less than 95°F (dry bulb thermometer), increased air flow across skin and less clothing decrease convective heat loads.

Other preventive measures include careful break-in of unacclimatized workers, decreasing heat loads in individuals with conditions that may increase the risk of heat disorders, and frequent drinking of water during exposure periods.

For all employees exposed to hot environments above the NIOSH recommended exposure limits, whether acclimatized or not, NIOSH recommends medical evaluations to determine an employee's physical ability to tolerate heat exposures at these evaluations include a comprehensive work and medical history, especially to elicit a history of known or suspected heat-related disorders or heat intolerance; a history of medical conditions, personal habits, or medications known to increase the risk of heat stress; and evidence of adaptability to heat. A comprehensive physical examination is recommended to identify conditions which may increase the risk of heat stress.[26]

Workers, supervisors, and managers should be educated about causative and risk factors, recognition of signs and symptoms, and preventive measures relating to heat disorders.

Self-regulation of individual heat exposures should be continued. The policy of removal from hot environments, however, should be based on an adequate knowledge of risk factors and recognition of signs and symptoms of heat stress by both supervisory personnel and workers.

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2. Operations Manager, Green Circle Growers, Inc.
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4. OSHA Region V, (Toledo, OH Area Office)
5 U.S. EPA Office of Pesticide Programs (Washington, DC)
6. Ohio Department of Agriculture, (Reynoldsburg, OH)

For the purpose of informing affected employees, a copy of this report should be posted by the employer in a prominent location at Plant 4 which is readily accessible to such employees for a period of 30 calendar days. The term "affected employees" means those workers determined by NIOSH to be exposed to the substances associated with the subject of the HHE. Therefore, because the employees of Green Circle Growers who work at the company's four other greenhouse locations are also potentially exposed to the same health risks as those described in this Final Report, a copy of this report should be posted in a prominent location at each of those workplaces as well.