HEALTH HAZARD EVALUATION REPORT

HETA 92-0381-2445
ORNAMENTAL PLANT NURSERIES
FLORIDA

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SUMMARY

In September 1992, the National Institute for Occupational Safety and Health (NIOSH) received requests for technical assistance from the Florida Department of Health and Rehabilitative Services (HRS) and the U.S. Environmental Protection Agency (EPA) concerning health complaints from growers and nursery workers in the ornamental plant industry. The requests concerned possible health effects associated with the use of Benlate DF®, a non-restricted use systemic fungicide whose active ingredient is benomyl.

During August 1-14, 1993, NIOSH investigators conducted an environmental exposure assessment and performed biological monitoring on ten nursery employees working at five nurseries currently using Benlate DF® in Florida. Workers were monitored during the weighing, mixing, and application of Benlate DF®, and during post-application crop handling, for (1) airborne concentrations of benomyl and its degradation products carbendazim, n-butyl isocyanate [BIC], and butyl amine; (2) skin contact with benomyl and carbendazim; and (3) urinary levels of the benomyl metabolite methyl-5-hydroxy-2-benzimidazole carbamate (5-HBC). Because Benlate DF® had been withdrawn from the market in March 1991, the exposure assessment was conducted at nurseries operating under an Experimental-Use Only EPA license to evaluate the effects of this fungicide on plants. As such, the weighing, mixing, and application practices were conducted on a continuous full-time basis by workers throughout the monitoring period, and not on the 10-14 day application cycle that would typically be expected during normal nursery operation.

NIOSH investigators also assessed the potential for exposure to residual Benlate DF® and its degradation products. Three nurseries with documented evidence of past use of Benlate DF® crop damage in 1991 and continuing plant growth problems were selected from a list of all registered nurseries in the State of Florida. For comparison purposes, two nurseries with no history of Benlate DF® use were also selected. An investigation conducted at these five nurseries during August 30 - September 3, 1993, included (1) area air sampling for benomyl and its degradation products, and (2) biological monitoring of 12 nursery workers for 5-HBC levels in the urine.

For the monitoring at nurseries currently using Benlate DF®, exposures to benomyl/carbendazim during mixing, application, and postapplication crop tending (plant trimming) activities were below the analytical level of quantification (LOQ). Detectable concentrations (31.3 micrograms per cubic meter [$\mu g/m^3$]) of benomyl were found during weighing activities. These levels are below the Occupational Safety and Health (OSHA) Permissible Exposure Limit (PEL) for total "nuisance" dust of 15,000 $\mu g/m^3$; there is no OSHA PEL specifically for benomyl. NIOSH has not established a Recommended Exposure Limit (REL) for benomyl. The American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) for benomyl is 10,000 $\mu g/m^3$. Personal exposures to BIC were less than 1 part per billion (ppb), or between the limit of detection (LOD) and LOQ for all mixing and application activities monitored. BIC concentrations, as with benomyl, were highest during weighing activities. A personal exposure of 7.2 ppb BIC (202-minute time-weighted average [TWA]) was measured during the weighing of Benlate DF® and WP®. Neither OSHA nor NIOSH has established a PEL or REL, respectively, for BIC. All personal butyl amine exposures were below the LOQ. The NIOSH REL and OSHA PEL for butyl amine are a ceiling limit of 5 parts per million (5000 ppb).

To ascertain whether skin contact to benomyl was occurring, workers wore cotton monitors underneath disposable latex gloves. Detectable concentrations of benomyl were found on 37 of 38 (97%) glove samples obtained from workers directly handling Benlate DF® and mixing, applying, and weighing Benlate WP® (another benomyl formulation). It is not known if the fungicide penetrated through the disposable latex glove (either by permeation or through a tear) or got underneath the latex glove from the worker's forearm. These results indicate exposure to, not absorption of, benomyl. Exposure limits for skin contact have not been established.

Detectable benomyl concentrations were found on 15 of 16 (94%) cotton glove monitors worn by workers who were trimming plants in an outdoor woody ornamental nursery 46 hours after the plants were drench treated with Benlate DF® and Benlate WP®. These results indicate that dislodgeable benomyl is still present on plants beyond the 24-hour re-entry interval and up to two full days after drench treatment. Detectable concentrations of benomyl were also found on patches placed on the lower body (thigh) of two workers conducting plant trimming. No detectable benomyl was found on any of the stomach or shoulder patches placed on these workers. This suggests that exposure occurred due to direct contact of the worker's lower body with the leaves of the treated crops.

Detectable concentrations of benomyl were found on 15 of 18 patches (83%) placed on the outside of the clothing of mixer-applicators directly handling Benlate DF®. The Tyvek® protective clothing appeared to be an effective barrier, as benomyl was detected on only 1 of 6 patches placed underneath the Tyvek® clothing.

Overall, the nursery workers had levels of 5-HBC in the urine ranging from 3.0-87.0 µmol/mol creatinine (median 23.8). The highest levels of 5-HBC in the urine (range 23.8-55.5 µmol/mol, median 39.7) occurred in two samples taken after weighing. Lower levels were found in ten samples taken after application and mixing activities (range <3.4-87.0 µmol/mol, median 24.7), and in five samples taken after post-application crop tending activities (range 3.0-46.2 µmol/mol, median 12.9).

For the monitoring conducted at nurseries with a past history or no history of Benlate DF® use, no detectable benomyl/carbendazim, BIC, or butyl amine was found during the air sampling. All nursery workers at sites where Benlate DF® had not been used since March 1991, had 5-HBC levels in urine below 5 µg/L or 3.5 µmol/mol creatinine. All except two samples had no detectable 5-HBC. No workers at sites where Benlate DF® had never been used had detectable 5-HBC in the urine.

EPA scientists from EPA Region IV, Athens, Georgia collected soil and water samples at five nurseries from September 13-15. The samples were analyzed by EPA at their Stennis Space Center, Mississippi laboratory. Neither benomyl or carbendazim was detected in any of the groundwater samples. Detectable levels of benomyl were found in the soil at nurseries currently using Benlate DF®, and those with a past history of benlate use. These results indicate that detectable levels of benomyl were present 2.5 years after the last use of Benlate DF®.

The industrial hygiene results and the biological monitoring findings indicate that the use of Benlate DF® in the ornamental industry can lead to absorption of the active ingredient. Weighing, mixing, and application involved the highest exposures. Except for the post-application crop tending activities, however, the work practices monitored were not considered typical of those found in the ornamental industry. Application occurred on a continuous, full-time basis and weighing occurred more frequently and over longer time periods than is usually seen in a typical 10-14 day application cycle. There is minimal, if any, exposure to benomyl at nurseries not currently using products containing benomyl. The health significance of these exposures to benomyl is not known. The health significance of benomyl and carbendazim measurements in soil is not known, as the presence of these contaminants in soil can not be extrapolated to exposure. Recommendations to reduce exposure are provided in this report.

KEYWORDS: SIC 0181 (ornamental nurseries), fungicide, Benlate DF®, benomyl, butyl amine, carbendazim, methyl-5-hydroxy-2-benzimidazole carbamate (5-HBC), n-butyl isocyanate (BIC)

1. INTRODUCTION

In September 1992, the National Institute for Occupational Safety and Health (NIOSH) received requests for technical assistance from the Florida Department of Health and Rehabilitative Services (HRS) and the U.S. Environmental Protection Agency (EPA) concerning health complaints from growers and nursery workers in the ornamental plant industry. The requests concerned possible health effects associated with the use of Benlate DF®, a non-restricted use systemic fungicide whose active ingredient is benomyl. Benlate DF® was voluntarily removed from the market in March 1991, due to allegations that it caused crop damage. In response to these requests, NIOSH investigators conducted an initial site visit in Florida on November 24 and 25, 1992. The objective of this visit was to gather additional information concerning health concerns associated with Benlate DF® in the ornamental industry. The NIOSH investigators met with representatives of HRS, the Florida Department of Agriculture and Consumer Services (DACS), the Farm Workers Association of Central Florida, growers, and investigators who had conducted recent medical evaluations. Site visits were conducted at two facilities to review work procedures and pesticide handling practices in the ornamental plant industry. During January 18-21, 1993, site visits were conducted at the remaining nurseries where Benlate DF® was currently being used under an EPA experimental license.

After reviewing the information obtained, the NIOSH investigators decided to conduct an exposure assessment study to investigate the potential for exposure to Benlate DF® and known degradation products among nursery workers in Florida.

On February 4, 1993, EPA organized a meeting in Arlington, Virginia, to discuss health concerns associated with benomyl. At this meeting, NIOSH was requested to utilize an advisory committee to provide an independent review of the study protocol. The members of the committee were selected from specialists suggested by HRS, the EPA, representatives of the Farm Workers Association of Central Florida, the Farmworkers Justice Fund, Inc., and the Florida Nursery-men and Growers Association in Florida. The committee included seven reviewers. Five were from academic institutions or governmental agencies not involved in the Benlate DF® investigation, and two representatives were from the Federal and State agencies collaborating with NIOSH in the study.

During August and September 1993, NIOSH investigators conducted an environmental exposure assessment and performed biological monitoring on nursery workers at ten ornamental plant nurseries in Florida. In September 1993, EPA collected soil and water samples at five of these nurseries and analyzed these samples for benomyl and carbendazim.

In May 1994, all study participants were informed in writing of the results of their urine tests and their personal air sampling results.

2. BACKGROUND[1]

Benlate was first registered with the U.S. Department of Agriculture in 1969 and was produced in a wettable powder formulation under the trade name Benlate WP®. The active ingredient is benomyl, which has been widely used in the United States and abroad as a systemic fungicide. In 1972, biocide oversight responsibilities shifted to the newly formed EPA. In 1977, the EPA launched a special review of Benlate after studies showed it caused a decrease in testis and epididymis weight in male rats, and at higher doses, caused a decreased sperm production (hypospermatogenesis). In high doses it was teratogenic in specific strains of rats. Benlate continued to be sold with revised labeling during the late 1970's and was considered a highly effective fungicide with few known human health effects. By 1986, Benlate had been shown to cause an increase of hepatocellular tumors in one specific strain of laboratory mice. This effect was not found in rats or other strains of mice. The EPA's advisory council reviewed the evidence and concluded that Benlate posed little threat to human health when used as recommended. In 1987, DuPont introduced a granulated formulation, Benlate DF (Dry Flowable)®, which made mixing the formulation with water easier and did not create dust. Benlate WP® was gradually phased out.

In 1989, crop damage associated with Benlate DF® was found to have occurred due to contamination with the herbicide atrazine, introduced at one of the subcontractor formulation sites. A partial recall of the product was initiated. In March 1991, DuPont voluntarily recalled Benlate DF® after becoming aware of possible product contamination. At the present time, it is no longer used commercially. By late spring 1991, reports of crop damage had been received by DuPont. DuPont was unable to identify a contaminant in the product. In September 1991, DuPont withdrew the registration for ornamental applications of Benlate DF®. In March 1992, the Florida Agriculture Commissioner requested that the Florida Department of Health and Rehabilitative Services (HRS) investigate growers' allegations of health effects related to Benlate DF®. HRS conducted telephone interviews with 75 growers who had used Benlate DF® and had experienced both crop damage and suspected health effects. The 12 most common complaints reported were: headaches (63%), stiff and achy joints (49%), shortness of breath (39%), fatigue (33%), rashes (30%), swollen joints (27%), sore and irritated throat (27%), nausea (27%), dizziness (25%), numbness and tingling in the extremities (23%), short term memory loss (20%), and nose bleeds (20%). All symptoms were self-reported. There was no comparison group, and there was no exposure assessment. The HRS telephone interview did not determine whether the occurrence of symptoms was unusual or whether symptoms were related to Benlate DF® exposure.

There are 7,438 active nurseries in Florida registered with DACS. The Florida Nursery Growers Association estimates that there are over 8,000 establishments in Florida in the categories of wholesale nursery, retail nursery, or wholesale nursery with retail facilities. Most complaints about crop damage in 1991 came from ornamental plant nurseries. Ornamental plant nurseries are mostly small operations usually employing one to five nursery workers. There are, however, a few nurseries with more than 100 workers. Nursery workers typically conduct a variety of tasks, including potting, packaging, crop-tending, and various maintenance chores. In general, most nurseries have one or more certified applicators for applying restricted-use pesticides. It has been estimated that approximately half of the ornamental nurseries used Benlate DF® in the past. In addition to fungicides, various pesticides, fertilizers, and other agricultural chemicals are commonly used in this industry.

3. STUDY DESIGN AND METHODOLOGY

3.1 Objectives

The primary objectives of this exposure assessment were to:

1. Assess the potential for farmworker exposure to benomyl and its main degradation products during the time Benlate DF® was used in commercial nurseries in Florida.

2. Assess current exposures to residual Benlate DF® and its degradation products in commercial nurseries.

3.2 Site selection

The HHE involved investigating the workers' potential for exposure to Benlate DF® in three groups of ornamental plant nurseries in the state of Florida. Specific criteria for the three groups are as follows:

a. **Nurseries where Benlate DF® currently was being used.** Ideally, a study to assess Benlate DF® exposure would be conducted at a site where Benlate DF® is used for routine commercial applications. Unfortunately, the removal of Benlate DF® from the market precluded this approach. There were, however, several sites in Florida where Benlate DF® was used for research purposes. Four of these sites were commercial nurseries where the manufacturer was utilizing Benlate DF® to investigate crop damage. There was also one research project where Benlate DF® was being used in nurseries by DACS scientists. These five nurseries will be referred to as **Group A sites**.

Background information

NIOSH investigators conducted site visits at four Group A nurseries in January 1993, and found that the work practices of the applicators of Benlate DF® were in accordance with the label instructions for the product. The personnel mixing and applying Benlate DF® wore latex gloves, safety glasses, and, in some cases, Tyvek® pants/suits. The applicators did not use respirators or goggles. Benlate DF® was applied by three applicators on a full-time basis (40 hours per week). The applicators traveled from site to site, and their only task was to apply varying concentrations of Benlate DF® and other fungicides to plants, in some instances up to eight times the maximum level indicated on the label. In contrast, past users of Benlate DF® performed applications once every 10-14 days, and the applicators were potentially exposed for a few hours during each application. All nursery workers performing post-application crop tending activities used no protective clothing, a situation which is likely to be comparable with past practices.

b. **Nurseries with documented evidence of past use of Benlate DF®, crop damage in 1991, and continuing plant growth problems.** Three nurseries that met these criteria were selected. The requirement for continuing plant growth problems was included to maximize the likelihood of detecting residual exposure. These three nurseries will be referred to as **Group B sites**.

c. **Nurseries involved nurseries with no history of Benlate DF® use.** For comparison purposes, two study sites with no history of Benlate DF® use were also selected. These two comparison nurseries will be referred to as **Group C sites**.

Study sites in Group A were identified by DACS and the manufacturer. Of the five studied sites, three were located within the eight-county study area (see below). The other two sites were in Alachua and Palm Beach Counties.

The study sites in Groups B and C were chosen at random from a list of all registered nurseries in the State of Florida. This list was provided to NIOSH by DACS. First, the sample selection was limited to sites in an eight-county study area (Hillsborough, Lake, Orange, Osceola, Pasco, Polk, Seminole, and Volusia), as most ornamental plant nurseries were located in these counties. Second, the selection was limited to sites that were registered as having 14,154 to 131,512 plants (between the 75th and 95th percentile). From the information we had obtained, smaller nurseries (< 14,154 plants) generally have only one or two employees. To minimize differences across nurseries and simplify sampling logistics, we preferred somewhat larger nurseries. In the largest nurseries (>131,512 plants), the workforce and pesticide application techniques may not be typical of most nurseries, however. So to insure a more representative selection of nurseries, these very large facilities were excluded. From the DACS nursery list, a total of 511 nurseries met the selection criteria. Twenty nurseries were randomly selected and the owners of these nurseries were notified in writing. The letter included background information on the Benlate DF® issue and the study objectives. One week after the letters were sent, NIOSH investigators phoned the recipients. The recipients were asked to respond to a series of questions to determine their history of Benlate DF® use, the presence of propagation houses and/or greenhouses (only those with such structures were included in the study), and the number of employees. The owners of all selected nurseries agreed to participate in the study. NIOSH investigators then categorized the responding nurseries into the appropriate study group. Six nurseries were in Group B, 3 were in Group

C, and 11did not meet the criteria. From among those that met the eligibility criteria, a sufficient number of nurseries were selected to obtain 10 to 15 workers in each group. It was determined that a sample size of 10 workers in each exposure group would be sufficient to detect differences in mean levels of 5-HBC of between 5 and 10 µg/dl with a power near 100%.

3.3 Industrial hygiene evaluation

Some nursery owners postulated that high temperature and humidity represented "worst-case" conditions concerning crop damage problems associated with Benlate DF®. For this reason, the exposure assessment was conducted in August.

The industrial hygiene evaluation consisted of the following components:

(1) Assessment of work practices, including personal protective equipment (PPE), associated with the use (mixing/application) of Benlate DF®, and post-application activities involving treated crops;

(2) Sampling to determine air concentrations of benomyl and its degradation products (carbendazim, n-butyl isocyanate, and butyl amine). At Group A sites, personal breathing zone sampling was conducted during the application of Benlate DF® and during post-application activities involving treated crops. Area sampling was also conducted at Group A sites. Only area sampling was conducted at Group B and Group C sites;

(3) Assessment of the potential for skin contact with Benlate DF® and its degradation products during use and post-application crop activities at Group A sites;

(4) Interviews with nursery owners and workers, and a review of nursery records at Group B and Group C sites, regarding past Benlate DF® use practices, as well as other agricultural chemicals;

(5) EPA personnel measured the level of benomyl and its degradation products in soil and water at selected sites; and,

(6) Assessment of dislodgeable residue by analyzing leaf samples collected at timed intervals after application of Benlate fungicide.

Information was collected in a manner to allow for the categorization of exposure, or exposure potential, by job description or activity. At each site evaluated, a review of agricultural chemicals in use other than Benlate DF® (e.g., other pesticides) was conducted. Field decisions were made at each site regarding the need to monitor for other agricultural chemicals. Samples were collected, labeled, stored, and shipped as required by the appropriate methodology to ensure sample integrity. Bulk samples and blanks were also collected.

Temperature and relative humidity (RH) measurements were obtained at all sites sampled. Dry bulb temperature and RH levels were determined at various intervals throughout the day. Instrumentation consisted of both a sling psychrometer (to assess dry bulb/wet bulb temperatures with subsequent RH determination from a psychrometric chart) and a calibrated TSI, Inc. model 8360 VelociCalc® meter with a digital readout. This unit is battery operated and has humidity and temperature sensors on an extendable probe. The temperature range of the meter is 14 to 140°F, and the humidity range is 20 - 95%. Temperature and RH as determined via standard dry bulb, wet bulb, and psychrometric chart correlated well with levels determined by the VelociCalc® meter.

Work practice and task specific information

At all sites, information was collected in a manner to allow for proper categorization of tasks, and to identify factors that may influence exposure. The information collected included the following:

- Facility description
- Job description
- Task description (specific)
- Materials used and frequency (application rate and volume)
- PPE worn (gloves, eye protection, etc.)
- Re-entry protocols
- Personal hygiene practices
- Food and beverage consumption for assessing potential pathways
- Safety training, applicator training
- Weather conditions (wind direction, relative humidity (RH), temperature)
- Adherence to label requirements

Inhalation assessment

Personal breathing zone (Group A only) and area (Groups A-C) air samples were collected for benomyl, carbendazim (MBC, CAS# 10605-21-7), n-butyl isocyanate (BIC, CAS# 111-36-4), and butyl amine (CAS# 109-73-9). The primary degradation products of benomyl are carbendazim and BIC. Butyl amine can be formed from BIC and water.[2] Therefore, it could be formed during mixing of benomyl with water, and in the humid conditions present at Florida nurseries. All samples were analyzed at the NIOSH laboratory in Cincinnati, Ohio.

Benomyl/carbendazim samples were collected on glass fiber filters using calibrated sampling pumps. The samples were analyzed via the Occupational Safety and Health Administration (OSHA) Stopgap Method protocol using high performance liquid chromatography (HPLC) with ultraviolet light detection. BIC samples were collected using two methods: (1) personal and area samples were collected on treated XAD-7 sorbent tubes per the 1988 OSHA Stopgap Method protocol, with subsequent HPLC analysis, and (2) area samples were collected using a NIOSH-developed impinger method using a dimethyl sulfoxide/tryptamine solution as the collecting media, with subsequent HPLC analysis. Sampling by the NIOSH-developed method was conducted side-by-side with sampling via the OSHA Stopgap Method. Butyl amine samples were collected on treated XAD-2 sorbent tubes, with subsequent HPLC analysis. A glass fiber filter was used as a prefilter for the BIC and butyl amine sampling, to prevent potential benomyl interference.

Personal breathing zone samples were obtained with calibrated air sampling pumps attached to the workers and connected, via Tygon tubing, to sample collection media placed in the employee's breathing zone. Monitoring was conducted throughout the employee's work-shift unless the monitoring was task-specific. Area samples were collected to determine relative levels at various locations, or when the monitoring method was not conducive to personal sampling (e.g., liquid impinger). After sample collection, the pumps were post calibrated.

Skin contact assessment

Skin exposure to pesticides is often considered to be a more significant portion of total exposure than inhalation.[3,4,5] An evaluation of the amount of material potentially available for absorption can provide estimates of skin exposure to contaminants. In some cases, where there is information on skin permeability and there is inhalation and biological monitoring data, skin contact assessments can theoretically provide more quantitative information on absorption or dose via the skin route. There are numerous techniques available to estimate the potential for skin contact; however, there is no standard protocol for the assessment of the degree of skin contact or the interpretation of data.

At sites where Benlate DF® was currently being used (Group A), cotton inspector's gloves were used as monitors to assess the potential for skin contact with benomyl/carbendazim during Benlate DF® application, and during post-application activities. This monitoring was not conducted to quantitatively evaluate whole body exposure, but to help evaluate the effectiveness of personal protective equipment, and identify areas where skin contact was occurring. Depending on the activity monitored, body patches (using 3" X 3" cotton gauze) were used to assess the potential for skin contact (e.g., the forearm during plant tending activities). Measurement of work rate (plants tended, treated, etc.) allows for comparison of exposures from different work practices. The samples were analyzed at the NIOSH analytical laboratory.

Dislodgeable residue

At Group A facilities, dislodgeable residue (benomyl/carbendazim) from plants was assessed to help evaluate the potential for skin contact during post-application crop handling activities. A leaf cutter was used to collect the samples to standardize the surface area sampled.[6] Samples were collected at different time intervals after Benlate DF® application to assess differences in dislodgeable residue concentrations. The samples were analyzed at the NIOSH analytical laboratory.

Soil sampling

Soil and water samples were collected at Groups A, B, and C sites and analyzed for benomyl and carbendazim, a known benomyl degradation product. The samples were collected by Region IV Environmental Protection Agency (EPA) investigators and analyzed by chemists at the EPA Pesticide Laboratory at the Stennis Space Center in Mississippi. The samples were used to compare relative concentrations at sites where Benlate DF® is currently used and where it was used prior to the March 1991, product recall and to provide information regarding the persistence of benomyl and its degradation products in the environment. The presence of contaminants in soil cannot be used to determine or estimate exposure, however.

3.4 Biological monitoring

Recruitment of study participants

Participation of individual workers in the study was by informed consent. Participants were limited to adults, 18 years of age or older, who were employed at the selected nurseries at the time of the study. For all nursery groups, the day before the study was conducted, NIOSH investigators visited the selected nurseries and met with nursery workers to explain the study and invite them to participate. At all sites, all selected workers received a fact sheet and an informed consent form.

Worker questionnaire

A questionnaire addressing demographics and work history information, and information on use of pesticides at work or at home was administered to each study participant during a private interview. The questionnaire was administered before the urine collection.

Specimen collection

Biological monitoring was conducted for workers at Groups A, B, and C sites. Urine levels of methyl-5-hydroxy-2-benzimidazole carbamate (5-HBC), a metabolite of benomyl, were measured. Analysis was by high-performance liquid chromatography with an electrochemical detector. The 5-HBC detection limit is reported to be 5 µg/L.[7]

Workers in Group A were asked to provide urine samples from all days that they worked during the study. Benlate DF® applications occurred on all these days. Collecting samples over extended periods for several days allowed us to account for day-to-day and diurnal variation, as well as the variation associated with exposure variability. There were two urine collecting periods per day, one between 12:00 p.m. and 5:00 p.m., and the other between 5:00 p.m. and 10:00 p.m. The participants were provided with plastic urine containers and asked to collect all urine samples during the above mentioned periods. The urine samples collected after work had to be kept by workers in the refrigerator over night and returned the next morning to NIOSH personnel at the workplace. The participants were asked to document date and time of the urine sample, and the time of the last urination before sampling. Participants were instructed to place the urine samples in a dark, cool area, preferably in the refrigerator, as soon as possible, and not to freeze the sample. To determine a baseline 5-HBC level workers were asked to provide a urine sample on the first monitoring day upon coming to work.

Workers in Groups B and C were asked to provide one urine sample per day on two different days. Fewer samples were needed than for Group A workers because of the less variable nature of the exposure in Groups B and C. The participants were provided with plastic urine containers and asked to collect all urine samples during the day between 12:00 p.m. and 10:00 p.m. They were asked to document date and time of the sample, and the time of the last urination before sampling.

The volume of the urine samples was measured by NIOSH investigators at each site, and a 75 milliliter aliquot was frozen with dry ice (-20^0 Celsius) as soon as possible after collection. The remainder of the urine was discarded. The urine samples were analyzed at T.N.O. Medical Biological Laboratory, Rijswijk, the Netherlands.

All samples were analyzed for 5-HBC and creatinine concentrations. Correction for creatinine (dividing 5-HBC concentration by creatinine concentration) is a procedure used to standardize measurements in urine, which varies in volume throughout the day.

4. EVALUATION CRITERIA

4.1 Metabolism of benomyl

Animal experiments have shown that benomyl is well absorbed after oral and inhalation exposure, but less well absorbed following skin exposure. Absorbed benomyl is rapidly metabolized to carbendazim and 5-HBC, which are excreted in the urine and feces, usually within 72 hours. In rats fed ^{14}C-labelled benomyl, the metabolites carbendazim and 5-HBC were found in the blood and in small amounts in the testes.[8,9] Small amounts of benomyl and its metabolites were also found in the kidney and liver. The tissue distribution showed no bioconcentration. In urine, the primary metabolite of benomyl is 5-HBC, some carbendazim is also present. In various species, approximately 70-90% of the orally administered dose of benomyl or carbendazim is excreted in the urine as 5-HBC within 24 hours.[10] In rats, 88% of an oral dose of carbendazim was excreted in urine as 5-HBC, while 86% of benomyl was excreted.[10] In contrast, when dogs were treated orally with benomyl, only 16% of the dose was excreted in the urine, mainly as 5-HBC, and 83% in the feces.[10] No human data on either skin penetration or metabolism of benomyl are available.

A recent study in humans involving carbendazim given orally, applied to the skin, and after an intravenous infusion showed that after oral administration an average of 15% (range 12-22%) of the dose was excreted as 5-HBC in urine.[11,12] This is in strong contrast to earlier reported data from most animal studies.[10] Likewise, an average of 15% (range 12-20%) of an intravenously administered dose of carbendazim is excreted as 5-HBC in the urine. This strongly suggests that human absorption of carbendazim after oral administration may be close to 100%. Application of carbendazim (30 mg) on both forearms (100 cm^2) for 4 hours resulted in an average of 3% absorption.

Without using radio-labelling, the only feasible way of monitoring the absorption levels of benomyl is to determine the levels of 5-HBC in urine. Potential sources of benomyl other than occupational exposure are food and beverage consumption. It is unknown what their impact is on the 5-HBC levels. The Food and Drug Administration allowable tolerances for benomyl in fruits range from 7 parts per million (pm) in apples to 35 pm in pineapples. In 1990, the FDA pesticide residue monitoring program analyzed 122 samples (5 domestic and 117 imported) for benomyl and related compounds (carbendazim). No residues in excesses of the tolerances were detected. Residues were found in 28 samples, at levels ranging from 0.05 pm (the limit of detection) in apples and cherries to 6.25 pm in pineapples.[13] Levels of 5-HBC in the urine may also be effected by use of the fungicides Tocsin®, Demeure®, Clears 33-36®, Fango-Felo®, Fango®, System®, Ziben®, BanRot®, which contain potentially interfering chemicals such as thiophanate-methyl and carbendazim.

4.2 Health effects of benomyl

Localized effects from handling benomyl fungicide products have been reported. Eye irritation has been reported when benomyl was used in enclosed areas, but the primary adverse health consequence associated with exposure to benomyl is contact dermatitis. Effects are most commonly noted at exposed sites such as hands and forearms. Despite the widespread use of benomyl, however, adverse skin effects are relatively rare.[14,15,16,17]

No deaths from ingestion of benomyl have been reported. There has been one unsubstantiated report of poisoning due to benomyl; [18] however, the diagnosis was later questioned.[19] Hematologic profiles of 50 male factory workers involved in the manufacture of benomyl were compared to those of 48 male workers who were not exposed to carbendazim. White blood cell count, red blood cell count, haemoglobin and hematocrit values were comparable between the two groups. No quantitative estimates of exposure was given for the factory workers.[20] There is no evidence of human carcinogenicity due to benomyl exposure.[8] The Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) is 15,000 $\mu g/m^3$ for total "nuisance" dust; there is no OSHA PEL specifically for benomyl.[21] The American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) for benomyl is 10,000 $\mu g/m^3$ as an 8-hour Time-weighted Average (TWA), based on skin irritation.[22] NIOSH has not established a Recommended Exposure Limit (REL) for benomyl, [23,24] but did not support a PEL of 10,000 $\mu g/m^3$ proposed by OSHA in 1988 because the PEL was based only on skin effects and did not consider reports of adverse reproductive effects of benomyl in experimental animals.[25]

4.3 Butyl Isocyanate

Dissociation of the benomyl molecule will form n-butyl isocyanate (BIC) and 2-methyl-benzimidazolecarbamate (MBC or carbendazim).[2,26] BIC is a colorless liquid with a boiling point of 46° C, and a vapor pressure of 17 mm Hg at 24° C.[27,28] BIC is a strong skin, eye, nose, and throat irritant.[29] Symptoms of exposure could include chest tightness, shortness of breath, difficulty in breathing and dry cough. Although there are no reports of respiratory sensitization in persons exposed to BIC, other isocyanates cause respiratory sensitization.[30] NIOSH has not established a REL for BIC, and there is currently no OSHA standard or ACGIH TLV for this substance. DuPont has established an internal Acceptable Exposure Limit of 10 parts per billion (ppb) as a full-shift TWA, and 20 ppb as a short-term 20 minute TWA for BIC.[31] The 1980 DuPont guideline was based on analogy with methyl isocyanate, and was subsequently updated in 1985, 1990, and 1991.

4.4 Butyl Amine

Butyl amine is a volatile, colorless liquid with a fishy ammonia-like odor and a vapor pressure of 82 mm Hg at 20° C.[22,24] Because the initial product formed when BIC reacts with water at typical soil pH is butyl amine, an assessment was conducted to evaluate exposure to this chemical.[2] Contact with butyl amine can cause severe burns of the skin and eye, and inhalation of the vapors can cause respiratory irritation.[22,30] Workers exposed to 5-10 pm noted irritation of the nose, throat, and eyes, and concentrations of 10-25 pm are considered unpleasant and intolerable by some.[30] The NIOSH REL and OSHA PEL for butyl amine are 5 pm (5000 ppb) as a ceiling limit, with a skin designation.[23,24] The skin notation indicates that airborne or direct exposure by the cutaneous route contributes to overall exposure.

5. RESULTS

5.1 Industrial hygiene evaluation

Site Descriptions: Group A Nurseries

Nursery A-1

Nursery A-1 is a 25 acre, open woody ornamental nursery that has been in operation since 1955. The DuPont Corporation leased 2 acres to conduct their plant damage experiments. Benlate DF had been used at this nursery prior to the March 1991 recall. DuPont applicators dispense fungicide (low pressure, high volume drench application only) from a tractor-pulled tank (employee walks next to the tractor with the drencher). Prior to each treatment, pre-weighed amounts of fungicide are added to the tank, which is then filled with water obtained from an on-site well. The mixer/applicator wore PPE consisting of light latex gloves and Tyvek® pants. No respiratory protection is worn. It takes 1 day to treat this 2-acre site. The nursery owners mix and apply other pesticides and fertilizers. The Benlate application rate is 1, 2, 4, and 8 lb/100 gallons H_2O. The standard (label) application rate is 1 lb/100 gallons H_2O, 108 lbs per acre. Other fungicides applied are Benlate WP® and Subdue®. Extra fungicide mixture is drained onto the ground. The DuPont project began in March 1992, and the plants were originally inside a greenhouse. Four nursery employees trim the treated plants (Wax Myrtles, Viburnum) every 4-6 weeks; no personal protective equipment is used during this activity. Sixteen acres where Benlate has never been used were being cleared to provide additional nursery space.
Table 1 shows dry bulb (DB) temperatures and RH levels at Nursery A-1 during the monitoring on August 2 and 4, 1993.

Table 1
Dry Bulb (DB) Temperatures and Relative Humidity (RH) Levels at Nursery A-1

August 2, 1993

Time	(DB)°F	%RH
10:03 a.m.	83	65
11:55 a.m.	89	52
02:15 p.m.	90.5	46

August 4, 1993

Time	(DB)°F	%RH
07:30 a.m.	75.5	96
09:35 a.m.	83	87
11:55 a.m.	88	67

Nursery A-2

The DuPont test area on Nursery A-2 consists of 2 acres of virgin (no prior Benlate use) land adjacent to an 80-acre production woody ornamental nursery. The greenhouse is constructed of plastic and polyethylene. There are 2 fans (thermostat controlled to activate at 85°F) on the greenhouse. Azaleas and Viburnum (outdoor), were drench treated (low pressure/high volume sprayer) during the monitoring. Blueberries, grown under a bird screen, were sprayed with a foliar backpack sprayer. During the backpack spraying, the applicator wore a full Tyvek® suit, in addition to disposable latex gloves and eye protection. Benlate DF® was applied in 1, 2 and 4 lb/100 gallon concentrations. The fungicides Benlate WP®, Captan, and Sipponate were also applied. A watering can was used to apply Benlate DF® (1,2,4 lb/100 gallon concentrations) to small Viburnum plants in the greenhouse.

Table 2 shows the temperature and RH levels during the monitoring at Nursery A-2 on August 3, 1993.

Table 2
Dry Bulb (DB) Temperatures and Relative Humidity (RH) Levels at Nursery A-2

Time	DB °F	%RH
09:05 a.m.	85	80
10:00 a.m.	86	73
01:40 p.m.	91	75
01:35 p.m.(inside greenhouse)	87	79

Nursery A-3

Nursery A-3 is a 26 acre facility established in 1929 and is currently producing foliage plant products (Gardenia, Peace Lily, ferns, palms). Except for the DuPont test area, Benlate® had not been used at this site since March, 1991. The DuPont test area is a grower-constructed greenhouse and screen house - 1 acre in size, adjoining. The site is leased by DuPont and DuPont workers do all fungicide applications. Nursery employees apply other pesticides and tend the product. The screenhouse (30-70% shade efficiency) is covered with 2 mil plastic in the winter. The plastic is removed on March 15, and put back up November 15. Prior to the DuPont tests, Benlate® had **never** been used in the screenhouse. The greenhouse is heated with gas heaters. Ventilation fans at one end are activated by thermostat (setpoint = 90°F). The fans are used for climate, not contaminant, control. Humidification through moistened pads is provided. Humidity levels are usually very close to or higher than outside humidity levels. A ground cloth is used to help control weeds.

Benlate DF® is applied every 14 days using the low pressure-high volume drench technique. DuPont employees spend 1 day every 10-14 days applying fungicide in this facility. Experimental treatments began in March 1992. There are over 100 treatment units, each consisting of about 40 plants in the 1 acre facility. Treatment sets are random and include duplicating the growers regime, no Benlate, Benlate DF®, WP®, no fungicide, other fungicides, inert ingredients, and 4X and 8X the application rate. Inert ingredients were also being tested.

DuPont air sampling to assess BIC levels has been conducted in this greenhouse. The highest concentration detected was an area sample that detected 6 parts per billion (ppb) adjacent to a plant after application.[26] Samples were collected in the greenhouse, shadehouse and an area where no Benlate was used.

Benlate is applied with a drencher equipped with two 25 gallon tanks and a 15 gallon rinse tank. The drencher is on a cart with wheels. A hose with a hand-squeeze control nozzle is used to dispense the Benlate. 40 PSI is used to dispense the material at about 2 pints/ft^2. After adding a measured amount of benlate to the tank, water is added and the mixture is mechanically agitated. Extra rinsate is dispensed onto plants or the ground.

Table 3 shows the temperature and RH levels during the monitoring at Nursery A-3 on August 9.

Table 3
Dry Bulb (DB) Temperatures and Relative Humidity (RH) Levels at Nursery A-3

Greenhouse

Time	DB °F	%RH
09:10 a.m.	83	74
10:22 a.m.	91	61
12:03 p.m.	97.2	52.2
02:10 p.m.	102.4	43
03:45 p.m.	98	48

Shadehouse

Time	DB °F	%RH
02:10 p.m.	96.2	40
03:36 p.m.	100	41

Nursery A-4

Nursery A-4 produces wholesale indoor foliage plants in greenhouse and shadehouse settings. The DuPont test area is a 1-acre shadehouse containing Areca palms, Spathophyllum, and Dracena Marginata placed on the ground. At the time of the evaluation, DuPont was treating plants in one section of the shadehouse (approximately 2000 ft^2 area). The low pressure-high volume drench method was used to apply Benlate DF® in 1,2,4, and 8 lb/100 gallon concentrations on the plants. Benlate WP® and Subdue® were other fungicides that were applied during the evaluation.

Table 4 shows the temperature and RH levels during the monitoring at Nursery A-4 on August 9, 1993.

Table 4
Dry Bulb (DB) Temperatures and Relative Humidity (RH) Levels at Nursery A-4

Time	DB °F	%RH
01:18 p.m.	91	60
02:12 p.m.	91.4	58
03:04 p.m.	91.5	52

Florida Department of Agriculture Greenhouse

DACS began conducting studies to investigate possible Benlate DF®-associated plant damage in November 1992. The test greenhouse, located in Gainesville, Florida, is a 216-square foot glass house referred to as an Orlyte greenhouse. The greenhouse is equipped with an evaporative cooler to help control temperature and humidity. During the NIOSH evaluation, DACS personnel were applying

Benlate DF® to petunias at the prescribed label rate (1 lb/100 gallons water, application every 2 weeks). Six different lots of Benlate DF®, obtained from growers, were used in the experiment. The proper amount of fungicide was weighed and mixed in the DACS Plant Pathology laboratory, and then carried to the greenhouse for application. Three DACS employees were conducting the tests. The fungicide was applied with a large plastic syringe directly to the potting soil of small petunia plants (60 milliliter per plant). DACS personnel wore disposable latex gloves during the weighing and application of Benlate DF®. No other personal protective equipment was worn. Table 5 shows the temperature and RH levels during the monitoring at the DACS Nursery on August 13, 1993.

Table 5
Dry Bulb (DB) Temperatures and Relative Humidity (RH) Levels at DACS Nursery

Time	DB °F	%RH
08:06 a.m.	75	87
08:30 a.m.(in lab)	77	60
09:30 a.m.	85	72
10:06 a.m. (in lab)	77	57
10:10 a.m.	84	77
10:55 a.m.	89	73
12:18 p.m.	90	65
01:24 p.m.	89	64

<u>Weighing station</u>

On August 5 and 9, small quantities of Benlate DF® and WP®, for use in the plant damage experiments, were weighed and packaged using a scale and small dispense tools. A one-week supply of fungicide was measured on each day. This work was conducted in an enclosed area (shed, building) on both days, and required the person conducting the weighing to continuously handle the dry fungicide. On August 5, the weighing took place in a portable metal shed. On August 9, weighing was conducted in a concrete block building adjacent to the greenhouse at Nursery #A-3. During the weighing, the worker wore a Tyvek® apron, arm gauntlets, latex gloves, safety glasses, and a 3M 8710 disposable dust mask (NIOSH TC-21C-132).

Table 6 shows the temperature and RH levels during the monitoring at the weighing station on August 5, 1993.

Table 6
Dry Bulb (DB) Temperatures and Relative Humidity (RH) Levels at the Weighing Station

Time	DB °F	%RH
08:10 a.m.	78	94
10:30 a.m.	83	76
11:45 a.m.	86	70

Site descriptions: Group B & C nurseries

Nursery B-1

Nursery B-1 is a 20,000 ft^2 steel frame and fiberglass greenhouse constructed in 1978 that has a double polypropylene ceiling with an air layer between the polypropylene sheets. The greenhouse has a shade screen on one side, and has fans to provide ventilation if necessary. Well water is used for irrigation. Benlate DF® was applied on plants (Aglanomea, Diffenbachia, Philodendron, Pothos) using both drench and spray application until the March 1991 recall. After the recall, no decontamination efforts were undertaken. No records of past use were available. Depending on business and time of year, there may be 1-3 employees, in addition to the owner, working at the facility. Subdue® and Captan 50 are fungicides currently used at the nursery.

Table 7 shows the temperature and RH levels during the monitoring at Nursery B-1 on August 31, 1993.

Table 7
Dry Bulb (DB) Temperatures and Relative Humidity (RH) Levels at Nursery B-1

Time	DB °F	%RH
09:50 a.m.	81	88
11:40 a.m.	90	70
02:30 p.m.	87	69
03:20 p.m.	90	62

Nursery B-2

Environmental monitoring at Nursery B-2 was conducted in a 35,000 ft^2 greenhouse with African Violets and ferns as the main crop. The greenhouse, constructed in 1983, had fiberglass sides and a double polyethylene roof with an air layer. Ventilation fans and "cool pads" (moistened pads) are used to control temperature and humidity. Plants are grown on tables in the greenhouse. Well water is used for irrigation. Ground cover mats cover the dirt floor. Benlate DF® was used in this greenhouse until the March 1991 recall. The fungicide was applied at label concentrations, and approximately 20-25 pounds of Benlate DF® were used annually. Application methods included drenching, misting, and spraying. After experiencing crop damage, the owner attempted to "decontaminate" the greenhouse by replacing all ground cover and irrigation pipes, cleaning all metal walls with bleach, and replacing potting soil (no ground soil was replaced). Fungicides currently in use include Clears®, Subdue®, and Daconil®. Records of past fungicide and other agricultural chemical use were available. Two employees, in addition to the owner, work at the nursery.

Table 8 shows the temperature and RH levels during the monitoring at Nursery B-2 on September 1, 1993.

Table 8
Dry Bulb (DB) Temperatures and Relative Humidity (RH) Levels at Nursery B-2

Time	DB °F	%RH
08:18 a.m.	76	90
10:23 a.m.	82	86
12:25 p.m.	84	85
02:45 p.m.	83	62

Nursery B-3

Nursery B-3 was established in 1960 and consists of several greenhouses where Spathophyllum, Dieffenbachia, and palms are grown. Environmental monitoring was conducted in a 45,000 ft^2 naturally ventilated greenhouse constructed of glass and steel. Plants are grown on corrugated Transite tables supported by cinder blocks. Well water is used for irrigation. According to nursery records, the last use of Benlate DF® in this greenhouse was February 22, 1991. Benlate DF® was applied at the label frequency and concentration (10-14 day cycle, 1lb/100 gal.). Spraying was the application method used (no drenching or dipping). No decontamination efforts were made after experiencing crop damage. Fungicides currently in use at this nursery are BanRot® and Subdue®. In addition to the owner, nine employees work at this nursery. Records of past fungicide and other agricultural chemical use were available.

Table 9 shows the temperature and RH levels during the monitoring at Nursery B-3 on August 31, 1993.

Table 9
Dry Bulb (DB) Temperatures and Relative Humidity (RH) Levels at Nursery B-3

Time	DB °F	%RH
08:40 a.m.	73	94
10:20 a.m.	81	78
11:00 a.m.	84	85
01:40 p.m.	90	67
04:10 p.m.	84	75

Nursery C-1

Nursery C-1 produces a variety of cacti and succulents. Environmental monitoring was conducted in the main terrarium house, a 12,000 ft^2 facility constructed in May, 1993. This is a wood frame facility with a polyethylene roof (not double lined) and a shade screen on two sides. The other sides are open. Plants are grown on wood or wire tables supported by cinder blocks. There is no covering on the dirt floor. Benlate (DF® or WP®) has **never** been used at this nursery. Some pesticides are used, and the fungicide BanRot® has been used in the past. Irrigation water is supplied from a local well.

Table 10 shows the temperature and RH levels during the monitoring at Nursery C-1 on September 1, 1993.

Table 10
Dry Bulb (DB) Temperatures and Relative Humidity (RH) Levels at Nursery C-1

Time	DB °F	%RH
09:50 a.m.	90	67
12:43 p.m.	100	48
02:22 p.m.	99	48
04:10 p.m.	92	76

Nursery C-2

Nursery C-2 is a woody ornamental and greenhouse facility that has been in operation since 1977. The primary crops grown in the greenhouse are Diffenbachia, Aglaneoma, and Pothos. The greenhouse structure is 28,000 ft^2, and is divided into two houses; a "pad and fan" house (16,000 ft^2, built in 1977) which has mechanical ventilation and moistened pads for humidity control, and a passive house (12,000 ft^2, built in 1983) with natural ventilation. The greenhouse is constructed of wood frame, fiber glass sides, and a double polyethylene (with air layer) roof. Benlate DF® has **never** been used at this facility. Benlate WP® was last use in 1985. Subdue® is occasionally used as a fungicide. Three employees and the owner operate the facility. A local well provides irrigation water.

Table 11 shows the temperature and RH levels at Nursery C-2 during the monitoring on September 1, 1993.

Table 11
Dry Bulb (DB) Temperatures and Relative Humidity (RH) Levels at Nursery C-2

Fan & Pad House

Time	DB °F	%RH
09:05 a.m.	80	87
11:40 a.m.	87	77
01:58 p.m.	90	68
03:30 p.m.	85	84

Passive House

Time	DB °F	%RH
09:07 a.m.	81	84
11:45 a.m.	90	72
02:01 p.m.	95	63
03:28 p.m.	86	84

<u>Air sampling results: Group A nurseries</u>

<u>Personal air sampling</u>

The results of the personal breathing zone air sampling conducted at Group A nurseries are detailed in Appendix Tables IH-1 - IH-7, and summarized in Table 12. Sampling was conducted during mixing and application, in both greenhouse and outdoor settings, and during post-application crop tending activities. Samples were collected for BIC, benomyl/carbendazim, and butyl amine. As previously noted, sampling was conducted concurrently with the biological (urine) monitoring. Six mixer/applicators and four workers conducting post-application activities in treated fields were monitored.

Table 12
Personal Air Sampling Results Summary: Group A Nurseries

Compound monitored	**Mixing/Applicating**		**Weighing**		**Trimming**	
	Avg.	Range	Avg.	Range	Avg.	Range
Benomyl	ND	ND	32.8 µg/m^3	31.3-(34.3) µg/m^3	ND	ND
Butyl Isocyanate	0.3 ppb	ND-0.9 ppb	6.6 ppb	5.9-7.2 ppb	(0.07) ppb	ND-(0.09) ppb
Butyl Amine	ND	NA	ND	NA	ND	NA

NOTE: µg/m^3 = Micrograms of contaminant per cubic meter of air sampled
ppb = Parts of gas or vapor per billion parts of air
ND = None Detected (below analytical limit of detection)
() = Concentration detected was between the analytical limit of detection and the level of quantification
Avg. = Average exposure for all monitored workers in that category
Range = Range of concentrations detected for all monitored workers in that category

The results show that exposures to benomyl/carbendazim during Benlate DF® mixing, application, and post-application crop tending (plant trimming) activities were below the analytical level of quantification (LOQ). One sample collected from a worker at the Florida DACS facility was between the analytical limit of detection (LOD) and the LOQ. This is not a surprising result as benomyl is not volatile and the potential for inhalation exposure during these activities is low. Detectable benomyl concentrations were found during the weighing of Benlate DF® and WP® on August 5 and 9, 1993 (Appendix Table IH-4). A concentration of 31.3 micrograms per cubic meter of air (µg/m^3) was found on August 5, and a concentration between the LOD and LOQ (34.3 µg/m^3) was found during the weighing activities on August 9. These levels are below the OSHA PEL of 15,000 µg/m^3 for "nuisance" dust,[20,21] and the ACGIH TLV of 10,000 µg/m^3 for benomyl. As previously mentioned, NIOSH has not established a REL for benomyl.[22,23]

Personal exposures to BIC were less than 1 part per billion (ppb), or between the LOD and LOQ, for all mixing and application activities monitored. One sample collected during post-application crop tending was between the LOD and LOQ (Worker ID# AD, Appendix Table IH-3). The monitoring showed that BIC concentrations, as with the benomyl samples, were highest during the weighing activities (Appendix Table IH-4). On August 5, a personal exposure of 7.2 ppb (202 minute time-weighted average [TWA]) was measured during the weighing of Benlate DF® and Benlate WP®, and a concentration of 5.2 ppb (39 minute TWA) was measured on August 9, 1993.

All personal butyl amine samples were below the LOQ, and all samples except one were below the LOD. A sample collected on August 3rd at Nursery A-2 (Appendix Table IH-2, Worker ID# AA) showed a concentration between the LOD and LOQ of approximately 12 ppb. As previously noted, the NIOSH REL for butyl amine is 5 parts per million (5000 ppb) as a ceiling limit.[22]

Area air sampling

The results of the area air monitoring are shown in Appendix Table IH-8. Area samples were collected to help identify contaminant concentrations at various locations where Benlate was being used. Additionally, area sampling allowed monitoring for extended periods to improve the sensitivity of the sampling technique. In general, the results of the monitoring were consistent with those found on the personal samples.

All benomyl/carbendazim samples collected at the woody ornamental nurseries, as well as in greenhouses, were below the analytical LOD. A benomyl concentration of 12.4 $\mu g/m^3$ was detected at the weighing station on August 5, and a concentration of 6.5 $\mu g/m^3$ was detected on a sample collected next to the weighing and mixing station at the Florida DACS facility.

The BIC sampling results showed concentrations ranging from 0.6 to 1.2 ppb inside greenhouses during and following application of Benlate fungicide. No BIC was detected in samples collected outdoors (e.g., woody ornamental). As with the personal samples, the highest BIC concentrations were detected in area samples collected at the weighing stations. A BIC concentration of 4.0 ppb was detected at the weighing station on August 5, and a concentration of 1.6 ppb was detected on a sample adjacent the weighing and mixing station at the Florida DACS facility.

None of the area samples detected butyl amine. All results were below the analytical LOD and are reported in Appendix Table IH-8 as "less-than" values.

As previously noted, BIC area sampling utilizing a NIOSH developmental monitoring method was also conducted. A total of 23 air samples using a dimethyl sulfoxide-tryptamine (DMSO-T) solution (impinger) were collected side-by-side with BIC samples collected using the OSHA stop-gap method. Due to two technical analytical problems, however, it was determined that the DMSO-T impinger method can not be reliably used for BIC measurement. Sample solutions and standard solutions of the BIC derivative were found to deteriorate with storage, and blank solutions of tryptamine in DMSO indicated the presence of an interference during HPLC analysis of approximately 30 times the LOD. For these reasons, no results from this monitoring method are available.

Air sampling results: Group B & C nurseries

The results of the area air monitoring conducted at Group B and C nurseries are shown in Appendix Table IH-9. As depicted in the table, no detectable levels of benomyl/ carbendazim, BIC, or butyl amine were found during this monitoring. The results reported in Appendix Table IH-9 are less-than values. This is not a surprising finding, as Benlate had not been used in Group B nurseries since March 1991, and had never been used in Group C nurseries.

Skin monitoring results

The results of the patch and glove analysis are detailed in Appendix Tables IH-10 - IH-15, and are summarized in Tables 13 and 14. For the patch tests, the results are reported in micrograms of benomyl per square centimeter of patch, over the sampling time (hours) that the patch was worn ($\mu g/cm^2/hr$). For the glove analysis, the results are reported, for each hand, in micrograms of benomyl per hour ($\mu g/hr$). Appendix Tables IH-10 - IH-15 also show the total amount of active ingredient (benomyl) that was handled during the sampling period, and whether or not the patch was worn outside or inside protective clothing. Total active ingredient was determined by tallying the total amount of Benlate handled, in grams, and dividing by 2 (the Benlate DF® and WP® used was 50% benomyl).

Table 13
Glove Monitoring Results Summary: Group A Nurseries
Benomyl Concentration (micrograms per hour [µg/hr])

Location	Mixing/Applicating		Weighing		Trimming	
	Avg.	Range	Avg.	Range	Avg.	Range
Left Hand	53.2	ND-398.9	556.1	158.7-953.5	43.3	ND -118.4
Right Hand	72.1	1.4-443.7	299.1	84.4-513.8	32.3	8.7-75

NOTE: µg/hr = Micrograms of benomyl detected over the time period the gloves were worn
ND = None Detected (below analytical limit of detection)
Avg. = Average exposure for all monitored workers in that category
Range = Range of concentrations detected for all monitored workers in that category

Table 14
Patch Monitoring Results Summary: Group A Nurseries
Benomyl Concentration (micrograms per centimeter squared per hour [$\mu g/cm^2/hr$])

Location	Mixing/Applicating		Weighing		Trimming	
	Avg.	Range	Avg.	Range	Avg.	Range
Thigh	0.19	ND-0.97	NA	NA	0.14	0.06-0.22
Stomach	0.45	ND-1.72	NA	NA	ND	ND
Shoulder	0.01	ND-0.03	NA	NA	ND	ND
Lower Leg	9.2	0.07-27	NA	NA	NA	NA

NOTE: $\mu g/cm^2/hr$ = Micrograms of benomyl per square centimeter of patch, detected over the time period the patch was worn
ND = None Detected (below analytical limit of detection)
NA = Not Applicable
Avg. = Average exposure for all monitored workers in that category
Range = Range of concentrations detected for all monitored workers in that category

Note that these results are indicative of exposure to benomyl, and not absorption. Currently, there is no exposure limit recommendation by NIOSH or regulatory agencies for the concentration of benomyl on work clothes or skin. As such, the health consequences of these exposures are not known.

Mixing, applicating, weighing

Glove monitors

To ascertain whether skin contact to benomyl was occurring, workers wore the cotton monitors underneath disposable latex gloves. Detectable concentrations of benomyl were found on 37 of 38 (97%) of glove samples obtained from workers directly handling Benlate DF® and mixing, applicating, and weighing Benlate WP® (another benomyl formulation). For the mixer/applicator tasks, the average left hand cotton monitor concentration was 53 µg/hr (standard deviation = 106), and 73 µg/hr for the right hand cotton monitor (standard deviation = 119). The portion of the cotton monitor that contacted the fungicide is not known, as the entire glove monitor was analyzed. Therefore, it is not known if the fungicide penetrated through the disposable latex glove (either by permeation or through a tear), or got underneath the latex glove from the worker's forearm. Contact on the upper arm, in conjunction with the workers' perspiration, could result in fungicide dripping down underneath the latex glove and contacting the cotton monitor. In any event, the latex gloves were not preventing benomyl from contacting the skin of the hand. These results indicate exposure, not absorption, to benomyl. (Exposure limits for skin contact have not been established.)

In general, the concentration of benomyl detected on the cotton glove monitors does not appear to be related to the total amount of active ingredient handled. One possible exception is the weighing activity. The largest quantity of active ingredient was handled during the weighing on August 5, and the highest concentration of benomyl (953.5 µg/hr) was found on the left hand of the worker conducting the weighing (Appendix Table IH-12). The relatively high concentration (191.3 µg/hr) detected on the right glove monitor from worker AH on August 13 (Appendix Table IH-15) may be attributed to a tear that occurred on the index finger of the latex glove. A new latex glove was donned after the tear was detected, but it was noted that the cotton monitor was moist, possibly due to contact with the benlate mixture.

Recovery studies for the glove samples showed that benomyl was recovered in the range of 53% to 63% from these samples. The glove data reported in this report was adjusted for recovery at a level of 60%.

Patches

Detectable concentrations of benomyl were found on 15 of 18 patches (83%) placed on the outside of the workers clothing. The Tyvek® protective clothing appeared to be an effective barrier, as benomyl was detected on only one (1/6, 16%) patch placed underneath the Tyvek® clothing. As with the glove monitors, the concentrations detected varied considerably, and did not appear to be related to the quantity of active ingredient
handled. All of the patches on the outside of the workers' clothing (e.g., Appendix Table IH-13, IH-14) placed on the lower portion of the body (thigh, shin) had detectable levels of benomyl. This was attributed to worker contact with the leaves of treated plants during application. Patch monitoring was not conducted during weighing activities.

Post-application crop handling

Detectable benomyl concentrations were found on 15 out of 16 (94%) cotton glove monitors worn by workers who were trimming plants in an outdoor woody ornamental nursery (Nursery #1, Appendix Table IH-11) 46 hours after being drench treated with Benlate DF® and WP®. Note that these workers **did not wear protective latex gloves** over the cotton glove monitors. The average left hand concentration was 43 µg/hr (standard deviation = 41), and 32 µg/hr (standard deviation = 23). The workers wore no protective clothing, and conducted the trimming activity in casual work clothes, short sleeve shirts, and tennis shoes. Some workers wore short pants. The trees were trimmed using two-hand clippers (approximately 2.5 feet long). In the 46-hour interim between fungicide treatment and trimming, the area experienced brief rainstorms as well as spray irrigation. These results indicate that dislodgeable benomyl is still present on plants beyond the 24 hour re-entry interval and up to two full days after drench treatment.

Detectable concentrations of benomyl were found on all patches placed on the lower body (thigh) of two workers conducting plant trimming. No detectable benomyl was found on any of the stomach or shoulder patches placed on these workers. It appears that exposure is occurring due to direct contact of the worker's lower body with the leaves of the crops being tended.

Soil/water sampling results

As previously noted, soil and water samples from Group A, B, and C nurseries were collected and analyzed for benomyl/carbendazim by EPA researchers. A total of 8 groundwater and 26 soil samples were collected and analyzed. Authoritative (biased) soil samples were collected from Group B and C nurseries, and representative samples were obtained from nursery #A-1. The way the soil samples were biased is that samples were collected from a location (based on interviews, observation) determined to have the highest probability of detecting a positive result. Groundwater was collected from on-site wells used for irrigation. All sampling, sample handling, chain of custody, quality assurance samples, etc.

were in accordance with the US-EPA, Region IV Environmental Services Division, *Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual*.

After collection, the samples were shipped to the EPA Office of Pesticides Program, Biological and Economic Analysis Division, Analytical Chemistry Branch, Environmental Chemistry Section, Stennis Space Center, Mississippi, for processing and analysis. The groundwater samples were analyzed by Method 631, The Determination of Benomyl and Carbendazim in Municipal and Industrial Wastewater, in *Methods for the Determination of Nonconventional Pesticides in Municipal and Industrial Wastewater, United States Environmental Protection Agency, Office of Water (WH-552), EPA 821 RR-92-002, April 1992*. The soil samples were analyzed by Method S-Benomyl, HPLC-UV Analysis of

Benomyl (as Carbendazim) in Soil Following Acid Hydrolysis and Liquid/Liquid Extraction, Florida Department of Environmental Protection, July 1993. Both methods contain QA procedures including method validation, control blanks, control spikes, matrix blanks, matrix spikes, etc. Confirmatory analysis was conducted on the sample extracts.

Groundwater results

Benomyl/carbendazim was not detected in any of the groundwater samples obtained from Group A, B, or C, nurseries. The limit of detection (LOD) for the analytical method was 10 micrograms per liter (µg/l). This was not an unexpected finding as benomyl is not considered a mobile chemical in soil, and is not considered to leach significantly. A 1988 groundwater study in the U.S.A did not detect benomyl in any of the 495 wells tested.[32]

Soil results

The results of the soil sampling are shown in Appendix Table IH-16. As noted, the samples collected from Group B and C nurseries were "biased" samples. As depicted in the table, detectable levels of benomyl were found at both A and B nurseries, and in two of the three samples collected at nursery C-2, a control nursery. As noted in the nursery description section, Benlate DF® has never been used at nursery C-2, and the last use of Benlate WP® was in 1985. Possible explanations for this result include the use of soil that contained benomyl that had been brought from another location, a different source of benomyl, or the presence of an interfering compound (although there was analytical confirmation of results via the use of an alternate HPLC column and UV wavelength, there was no mass spectroscopy confirmation of benomyl/carbendazim). The highest concentrations of benomyl were detected at nursery B-2. These results indicate that detectable levels of benomyl were present 2.5 years after the last use of Benlate DF®. The significance of these levels in soil, from the standpoint of human health, is not known, as the presence of contaminants in soil can not be extrapolated to exposure.

Bulk sample results

Bulk samples of Benlate DF® and WP® (dry powders and application solutions), were collected to quantify the benomyl concentration. These samples were analyzed at the NIOSH laboratory by solubilizing the benomyl in acetonitrile, with subsequent analysis by high performance liquid chromatography.

Samples of the 2 lb/100 gallon and 8 lb/100 gallon Benlate DF® solutions used in the DuPont plant damage experiments collected at Nursery #1 showed a benomyl concentration of 0.9 and 3.7 lbs/100 gallons. A sample of the 8 lb/100 gallon Benlate WP® solution obtained at Nursery #3 showed a benomyl concentration of 6 lbs/100 gallon. Note that the Benlate DF® and WP® used to prepare these application solutions contained 50% benomyl.

Bulk samples of the Benlate DF® and WP® powders were collected from the supply used by the DuPont applicators, as well as from one of the lots used by the Florida DACS personnel. The concentrations of benomyl found in these samples ranged from 52.3 to 56.7%.

Dislodgeable residue sampling results

Leaf samples were obtained at various intervals after application of Benlate DF® on various crop types from woody ornamental and greenhouse nurseries. The samples were obtained to determine the amount of benomyl residue remaining on the leaves, and degradation over time. Numerous analytical difficulties, however, were encountered during the processing of these samples, and no valid results are available.

5.2 Biological monitoring

The total number of nursery workers working at nurseries in Florida where Benlate DF® was in use at the time of our study (Group A) was limited to 11 individuals. Ten of these workers participated in our study. One nursery worker was excluded from participation as he had performed applications of many unknown chemicals to plants outside his workplace. Potential exposure to Benlate DF® among these workers varied. At the commercial nursery sites, two workers weighed, mixed, and applied fungicide (Benlate DF® and others) full-time (40 hours/week), one other worker only during 2 days per week. Four workers entered Benlate DF® treated areas 46 hours after application (tending crops, etc.). Three workers mixed and applied Benlate DF® at the DACS research site. Twelve of the 13 nursery workers participated at the Group B nurseries, and 9 of the 11 at the Group C nurseries participated. Both groups (B and C) included post-application nursery workers and mixers/applicators. All mixers/applicators also performed post-application nursery work.

A total of 31 of the 35 nursery workers completed the questionnaire, for a participation rate of 89%. Group-specific rates ranged from 75% to 92% [Table 15].

Table 15
Participation Rate by Nursery Group

Nursery Group	Number of Participants Selected	Actual Participants	
		Number	Percent
A	11	10	91%
B	13*	12	92%
C	12*	9	75%

* randomly selected

The mean age of the study participants was 33 years (range: 19 years to 56 years); 61% were female. Six percent were self-reported Asian, 6% African-American, 36% Hispanic, and 52% of non-Hispanic European ancestry. The mean length of employment was 8 years (range: 4 months to 35 years) in the ornamental plant industry and 6 years (range: 4 months to 35 years) at the current nursery. Twenty-three percent of the workers were weighers, mixers and/or applicators, and 77% were labor nursery workers. All participants worked full-time (five days per week, 40-45 hours) year-round, except for one person who worked seasonally full-time. Nursery Group A included a higher percentage of persons of non-Hispanic European ancestry, and Nursery Group C included a higher percentage of Hispanic persons, as well as a higher percentage of females. Nursery Group C workers had the shortest tenure in the ornamental plant industry, as well as in their recent nursery [Table 16].

Table 16
Demographics

Nursery Group	A	B	C
Mean Age (in years)	35	36	28
Percent Female	50%	58%	78%
Years working in current nursery	9	5	3
Years working at any ornamental plant nursery	10	11	5

During the month previous to the study, none of the participants had applied pesticides for their friends, neighbors, or relatives; nor had they used pesticides at their homes. At that time, they had worked only at their current nurseries and not at any other locations. None of the participants were known to have used the chemicals Tocsin®, Demeure®, Clears 33-36®, Fango-Felo®, Fango®, System®, Ziben®, or BanRot® during the previous month. (These chemicals may affect the level of 5-HBC in the urine.)

All 31 nursery workers who completed the questionnaire also provided at least one urine sample. In all, 96 urine samples were collected for analysis of 5-HBC. Four specimen samples were split and submitted to the laboratory as two unrelated samples. In addition, NIOSH laboratory personnel added known amounts of 5-HBC to 13 of 14 urine samples of NIOSH office personnel, who were not exposed to Benlate DF® or any of the 8 chemicals described in the previous paragraph. All 14 samples were submitted to the laboratory as 14 unrelated samples for laboratory quality control purposes. 5-HBC in urine was determined according to the method of Leenheers, et al.[7,33] The average recovery for the quality-control samples was 99% of the quantity of 5-HBC added to the specimens (range: 88% to 120%). The precision of the creatinine-adjusted analysis was estimated using the data from the 4 split field specimens and the 11 quality-control samples. Expressed as relative standard deviation, the precision ranged from 1% to 14% and averaged 6.1%.

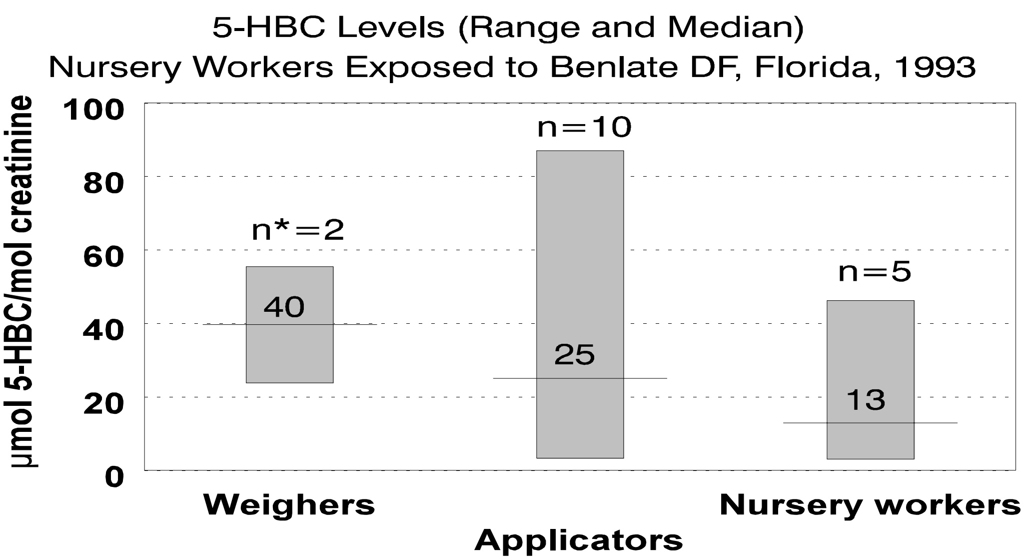
Of the 96 urine samples, 14 were excluded from the analysis because of very low creatinine concentration (< 5 mmol/L) and 1 was excluded because of an unknown interference with the 5-HBC peak. The highest 5-HBC concentration (µmol/mol creatinine) in the urine of each Group A participant on the day of exposure and the highest level from each Group B and C participant over the two sampling days was used for statistical analysis. (Data for each day were included for participants in Group A who were tested on more than one day.) The detection limit for 5-HBC was 5 µg/L. If the concentration of 5-HBC level was below this limit, the value of the detection level itself (5 µg/L) was used for calculation.

Nursery Group A

Workers in Group A provided urine samples for all days that they worked during the study. On all these days Benlate DF® applications occurred, or in the case of non-applicators, had occurred 2 days (46 hours) prior to the day of the plant handling tasks. Fifty-four urine samples from 10 nursery workers were collected during 1-5 workdays. The workers were classified into three job groups: (1) mixing and applying Benlate DF® to ornamental plants; (2) cutting and trimming plants, cleaning up, and other miscellaneous nursery work duties (at least 46 hours after Benlate DF® had been applied); and (3) weighing Benlate DF® for the experiments. (This work is not typical for the ornamental plant industry, as workers normally do not spend several hours weighing Benlate DF®.) Ten work days of applying and mixing Benlate DF®, five work days of cutting and trimming plants, cleaning up, and other miscellaneous nursery work duties, and two workdays of weighing Benlate DF® were monitored. All sampling data for Group A workers are presented in Appendix Table M-1.

Group A workers had levels of 5-HBC in the urine ranging from 3.0-87.0 µmol/mol creatinine (median 23.8). The highest levels of 5-HBC in the urine (range 23.8-55.5 µmol/mol, median 39.7) occurred in two samples taken after weighing. Lower levels were found in ten samples taken after application and mixing activities (range <3.4-87.0 µmol/mol, median 24.7), and in five samples taken after post-application crop tending activities (range 3.0-46.2 µmol/mol, median 12.9). [Figure 1]

Figure 1



n = Number of person-days sampled. The highest urine concentration of each day was used for the calculation. If this was below the detection level, the value of the detection level itself was used for calculation

The urine sample collection strategy was not designed to describe the levels of 5-HBC, over time, after exposure. However, five morning urine samples of mixers/applicators collected between 40 to 90 hours after exposure to Benlate DF® contained 5-HBC levels near or below the detection level (range: <2.2 to 8.0 µmol/mol creatinine), suggesting that most or all 5-HBC is excreted in the urine within 2-4 days. These findings are consistent with previous data.[7]

Nursery Group B

Twenty-four urine samples from 12 nursery workers were collected on two different days. All nursery workers, performing tasks such as mixing and applying pesticides to ornamental plants, cutting and trimming plants, cleaning up, and other miscellaneous nursery work duties, had 5-HBC levels below 3.5 µmol/mol creatinine. Two samples had detectable amounts of 5-HBC. All sampling data for Group B workers are presented in Appendix Table M-2.

Nursery Group C

Eighteen urine samples from nine nursery workers were collected on two different days. None of the workers, performing tasks as mixing and applying pesticides to ornamental plants, cutting and trimming plants, cleaning up, and other miscellaneous nursery work duties, had detectable amounts of 5-HBC. All sampling data for Group C workers are presented in Appendix Table M-3.

6. CONCLUSIONS

Personal breathing zone concentrations were below the ACGIH TLV for benomyl and the NIOSH REL for butyl amine during the application of Benlate DF®, and during post-application crop tending activities. NIOSH, OSHA, and the ACGIH have not established exposure criteria for BIC; however, all results were below the DuPont AEL of 10 ppb for BIC. The highest concentrations of benomyl and BIC were detected during the weighing of Benlate DF® and WP®. This was not an unexpected finding, as weighing entails more direct contact with the fungicide concentrate than any other activity assessed. Note, however, that continuous weighing of fungicide for several hours is not considered to be a normal activity of nursery workers, as batch preparation of numerous pre-weighed lots of fungicide is not typically conducted. BIC, benomyl, or butyl amine were not detected in the air samples from Group B and C nurseries.

Detectable levels of benomyl were found on 97% of the glove samples obtained from workers directly handling Benlate DF® and WP®. As previously noted, there are no standards or guidelines for acceptable levels of benomyl on skin or clothes. As the glove monitors were worn underneath the workers' latex gloves, this indicates the latex gloves are not preventing contact with benomyl. A longer and more durable type of protective glove is warranted. Detectable levels of benomyl were also found on gloves and patches obtained from workers conducting post-application crop-tending activities 46 hours after a drenching application, indicating that dislodgeable residue is still present beyond the standard 24 hour re-entry interval. The leaf samples, which could have provided information on dislodgeable residue degradation over time, could not be accurately analyzed. Moreover, the health consequences of this exposure are not known. Thus, recommendations concerning re-entry interval modifications can not be made from these data.

No detectable benomyl was found in any of the water samples collected and analyzed by the US EPA. Detectable levels of benomyl were found, however, in soil samples collected from Group A, B, and one C nurseries. As the C nursery supposedly never used Benlate DF®, this was an unexpected finding. Possible explanations include potential analytical interference or the presence of soil obtained from another site that contained benomyl. The presence of benomyl in soil cannot be extrapolated to human exposure, and the health implication of this finding is unknown.

NIOSH investigators found levels of 5-HBC in the urine of nursery workers exposed to Benlate DF® during weighing, mixing, application, and plant handling tasks. With two exceptions detectable levels of 5-HBC were found neither in urine of workers from facilities where Benlate DF® was used before 1991 (and where residual exposure to Benlate DF® degradation products has been hypothesized), nor in urine of workers from facilities where Benlate DF® was never used.

7. RECOMMENDATIONS

1. Eye Protection: Eye protection was not consistently worn by personnel handling, mixing, or dispensing Benlate® DF or other fungicides. Protective eye wear (e.g., chemical splash goggles) should be worn to prevent eye contact with chemicals during handling. Quick drenching facilities (emergency eye wash station) should also be available in the event of chemical contact with the eyes.

2. Food and Beverage Consumption: We observed personnel eating and drinking near the Benlate® DF mixing and weighing area at the DACS facility. Tables potentially used for storage or dispensing of chemicals were also used as food tables. In general, to reduce the potential for exposure via ingestion, food and beverages should not be consumed in chemical handling areas.

3. Chemical Transportation: At the DACS facility, the Benlate® DF mixture was transported from the main laboratory to the greenhouses in a beaker, often by personnel who must open and close doors while carrying other equipment. To reduce the potential for a spill, containment transport devices (e.g., bottle buckets) should be used for this activity. Most safety equipment suppliers carry these types of devices for hand-carried chemicals.

4. Protective Clothing: Skin exposure to benomyl was occurring among employees working in treated areas 46 hours after application (past the reentry interval). This suggests that the re-entry interval may need to be re-evaluated. These workers were not wearing any protective clothing during these post-application activities. The health consequences of this skin exposure are not known. Until such time that the re-entry interval is examined, as a precautionary measure to reduce the potential for exposure, employees working with treated crops should wear protective gloves and lightweight protective pants (e.g., Tyvek) at all times. Note that wearing additional protective equipment may put a burden on workers (e.g., heat stress) that must be taken into account. Additionally, the latex gloves worn by workers during application are not preventing the fungicide from contacting the skin of the hand. A more durable and longer chemical protective glove should be worn. The gloves should be cuffed to prevent drips from contacting the upper arm.

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13. Tropical Ornaments, Delray Beach, Florida
14. Valley Cactus, Zellwood, Florida
15. OSHA Region IV

For the purpose of informing affected employees, copies of this report shall be posted by the nursery growers in a prominent place accessible to the nursery workers for a period of 30 calendar days.

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APPENDIX TABLES

Table IH-1
Personal Air Monitoring Results: Nursery #A-1
Benlate DF/WP Application: August 2, 1993
HETA 92-0381

Worker	Activity/Application Technique	Sample #	Sampling Period	Duration (min)	Contaminants Sampled	Concentration	
						PPB	**µg/m³**
AA	Drenching Woody Ornamental Plants with Benlate DF. Used 1 and 2 pound/100 gallon concentrations.	BIC-51 BAM-301 BEN-2	07:57 - 11:48	231	Butyl Isocyanate Butyl Amine Benomyl	(0.1) <6.1	 <2.9
		BIC-56 BAM-306 BEN-10	13:14 - 15:38	144	Butyl Isocyanate Butyl Amine Benomyl	0.7 <9.8	 <4.6
AB	Drenching woody ornamental plants with Benlate DF and WP. Used 1, 2, 4, and 8 pounds per 100 gallons water concentrations.	BIC-57 BAM-307 BEN-11	07:56 - 11:47 13:15 - 15:40	376	Butyl Isocyanate Butyl Amine Benomyl	(0.09) <3.5	 <1.9

NOTE:PPB = Parts of gas or vapor per billion parts air
$\mu g/m^3$ = micrograms of contaminant per cubic meter of air sampled
() = concentration detected was between the analytical limit of detection and the level of quantification
< = less than (no contaminant detected); the concentration listed is the analytical limit of detection.
The analytical limit of detection for the contaminants sampled was:
butyl isocyanate = 0.01 microgram (µg) per sample
butyl amine = 0.3 µg per sample
benomyl = 0.2 µg per sample

Table IH-2
Personal Air Monitoring Results: Nursery #A-2
Benlate DF/WP Application: August 3, 1993
HETA 92-0381

Worker	Activity/Application Technique	Sample #	Sampling Period	Duration (min)	Contaminants Sampled	Concentration PPB	Concentration µg/m³
AA	Spraying and drenching woody ornamental plants with Benlate DF and WP. Used 1, 2, and 4 pounds/100 gallons water concentrations.	BIC-58 BAM-308 BEN-12	08:09 - 10:40 09:13 - 10:40 08:03 - 10:40	151 87 151	Butyl Isocyanate Butyl Amine Benomyl	0.4 (12.3)	< 4.2
AB	Used backpack sprayer to apply Benlate DF and WP to blueberry plants under a bird cover.	BIC-59 BAM-309 BEN-13	08:03 - 10:49	166	Butyl Isocyanate Butyl Amine Benomyl	(0.09) <5.7	<3.9
AC	Used watering can to manually drench ornamental plants with Benlate DF and WP inside a greenhouse. Used 1, 2, and 4 pound/100 gallon concentrations.	BIC-65 BAM-312 BEN-19	13:23 - 15:09	106	Butyl Isocyanate Butyl Amine Benomyl	(0.07) <8.4	<6.1

NOTE:PPB = Parts of gas or vapor per billion parts air
µg/m³ = micrograms of contaminant per cubic meter of air sampled
() = concentration detected was between the analytical limit of detection and the level of quantification
< = less than (no contaminant detected); the concentration listed is the analytical limit of detection.
The analytical limit of detection for the contaminants sampled was:
butyl isocyanate = 0.01 microgram (µg) per sample
butyl amine = 0.3 µg per sample
benomyl = 0.2 µg per sample

Table IH-3
Personal Air Monitoring Results: Nursery #A-1
Trimming Plants: August 4, 1993
HETA 92-0381

Worker	Activity/Application Technique	Sample #	Sampling Period	Duration (min)	Contaminants Sampled	Concentration PPB	Concentration µg/m³
AG	Trimming Woody Ornamental Plants that had previously (46 hours) been treated with Benlate DF and WP.	BIC-69 BAM-315 BEN-22	07:25 - 11:31 07:25 - 11:31 09:00 - 11:31	246 246 151	Butyl Isocyanate Butyl Amine Benomyl	<0.03 <3.6	<4.3
AF	Trimming Woody Ornamental Plants that had previously (46 hours) been treated with Benlate DF and WP.	BIC-71 BAM-322 BEN-24	07:25 - 11:31	246	Butyl Isocyanate Butyl Amine Benomyl	<0.04 <5.1	<2.9
AD	Trimming Woody Ornamental Plants that had previously (46 hours) been treated with Benlate DF and WP.	BIC-70 BAM-321 BEN-25	07:25 - 11:31	246	Butyl Isocyanate Butyl Amine Benomyl	(0.07) <3.6	<2.6
AE	Trimming Woody Ornamental Plants that had previously (46 hours) been treated with Benlate DF and WP.	BIC-68 BAM-314 BEN-23	07:25 - 11:31	246	Butyl Isocyanate Butyl Amine Benomyl	(0.09) <3.7	<2.6

NOTE:PPB = Parts of gas or vapor per billion parts air
µg/m^3 = micrograms of contaminant per cubic meter of air sampled
() = concentration detected was between the analytical limit of detection and the level of quantification
< = less than (no contaminant detected); the concentration listed is the analytical limit of detection.
The analytical limit of detection for the contaminants sampled was:
butyl isocyanate = 0.01 microgram (µg) per sample
butyl amine = 0.3 µg per sample
benomyl = 0.2 µg per sample

Table IH-4
Personal Air Monitoring Results: Weighing Room
Benlate DF/WP Weighing: August 5 & 9, 1993
HETA 92-0381

Worker	Activity/Application Technique	Sample #	Sampling Period	Duration (min)	Contaminants Sampled	Concentration PPB	Concentration µg/m^3
AA	Weighing small (100 gram) amounts of Benlate DF/WP in enclosed portable shed, using scale and small dispense tools. August 5, 1993	BIC-73 BAM-317 BEN-27	08:05 - 11:27	202	Butyl Isocyanate Butyl Amine Benomyl	7.2 <4.5	 31.3
AA	Weighing small (100 gram) amounts of Benlate DF/WP in enclosed building, using scale and small dispense tools. August 9, 1993	BIC-84 BAM-326 BEN-36	11:03 - 11:42	39	Butyl Isocyanate Butyl Amine Benomyl	5.9 <22.8	 (34.3)

NOTE:PPB = Parts of gas or vapor per billion parts air
µg/m^3 = micrograms of contaminant per cubic meter of air sampled
() = concentration detected was between the analytical limit of detection and the level of quantification
< = less than (no contaminant detected); the concentration listed is the analytical limit of detection.
The analytical limit of detection for the contaminants sampled was:

Table IH-5
Personal Air Monitoring Results: Nursery #A-3
August 9, 1993
HETA 92-0381

Worker	Activity/Application Technique	Sample #	Sampling Period	Duration (min)	Contaminants Sampled	Concentration PPB	Concentration µg/m^3
AB	Drenching Ornamental Plants with Benlate DF and WP inside greenhouse and shadehouse. Used 1, 2, 4, 8 pound/100 gallon concentrations.	BIC-92 BAM-332 BEN-44	09:44 - 12:30 14:06 - 15:37	166 91	Butyl Isocyanate Butyl Amine Benomyl	0.8 <3.8	<2.5

NOTE:PPB = Parts of gas or vapor per billion parts air
µg/m^3 = micrograms of contaminant per cubic meter of air sampled
() = concentration detected was between the analytical limit of detection and the level of quantification
< = less than (no contaminant detected); the concentration listed is the analytical limit of detection.
The analytical limit of detection for the contaminants sampled was:
butyl isocyanate = 0.01 microgram (µg) per sample
butyl amine = 0.3 µg per sample
benomyl = 0.2 µg per sample

Table IH-6
Personal Air Monitoring Results: Nursery #A-4
Benlate DF/WP Application: August 10, 1993
HETA 92-0381

Worker	Activity/Application Technique	Sample #	Sampling Period	Duration (min)	Contaminants Sampled	Concentration	
						PPB	µg/m³
AA	Drenching Ornamental Plants with Benlate DF and WP inside shadehouse. Used 1, 2, 4, 8 pound/100 gallon concentrations.	BIC-504 BAM-334 BEN-46	13:10 - 15:12	122	Butyl Isocyanate Butyl Amine Benomyl	0.7 <7.2	<5.4
AB	Assisting applicator and mixing Benlate DF and WP inside shadehouse. Moving hoses and drench machine. Mixed 1, 2, 4, 8 pound/100 gallon concentrations.	BIC-503 BAM-335 BEN-47	13:08 - 15:12	124	Butyl Isocyanate Butyl Amine Benomyl	0.9 <8.4	<4.9

NOTE:PPB = Parts of gas or vapor per billion parts air
µg/m³ = micrograms of contaminant per cubic meter of air sampled
() = concentration detected was between the analytical limit of detection and the level of quantification
< = less than (no contaminant detected); the concentration listed is the analytical limit of detection.
The analytical limit of detection for the contaminants sampled was:
butyl isocyanate = 0.01 microgram (µg) per sample
butyl amine = 0.3 µg per sample
benomyl = 0.2 µg per sample

Table IH-7
Personal Air Monitoring Results: Florida Department of Agriculture Test Greenhouse
Benlate DF Application: August 13, 1993
HETA 92-0381

Worker	Activity/Application Technique	Sample #	Sampling Period	Duration (min)	Contaminants Sampled	Concentration	
						PPB	µg/m³
AI	Weighing, mixing and assisting with the application of Benlate DF (1lb/100 gal.) in a greenhouse.	BIC-508 BAM-338 BEN-605	08:49 - 13:35	286	Butyl Isocyanate Butyl Amine Benomyl	0.5 <4.7	<2.1
AH	Weighing, mixing, and applicating small (300-900 ml) volumes of Benlate DF (1lb/100 gal.) using a plastic syringe to drench 4" plant pots.	BIC-507 BAM-339 BEN-604	08:45 - 13:33	288	Butyl Isocyanate Butyl Amine Benomyl	0.8 <3.8	(4.2)
AJ	Weighing, mixing, and applicating small (300-900 ml) volumes of Benlate DF (1lb/100 gal.) using a plastic syringe to drench 4" plant pots.	BIC-509 BAM-341 BEN-606	09:08 - 10:55 10:57 - 13:41	107 164	Butyl Isocyanate Butyl Amine Benomyl	0.4 <3.5	<2.3

NOTE:PPB = Parts of gas or vapor per billion parts air
µg/m^3 = micrograms of contaminant per cubic meter of air sampled
() = concentration detected was between the analytical limit of detection and the level of quantification
< = less than (no contaminant detected); the concentration listed is the analytical limit of detection.
The analytical limit of detection for the contaminants sampled was:

butyl isocyanate = 0.01 microgram (µg) per sample
butyl amine = 0.3 µg per sample= 0.2 µg per sample

Table IH-8
Area Air Sampling Result: Group A Nurseries
HETA 92-0381

Date	Location/Description	Sample #	Sampling Period	Duration (min)	Contaminants Sampled	Concentration PPB	Concentration µg/m³
8/02	Nursery #1, Juniper area, outdoor woody ornamental. During Benlate DF/WP application.	BIC-54	08:40 - 15:14	394	Butyl Isocyanate	<0.02	
		BAM-304			Butyl Amine	<2.5	
		BEN-7			Benomyl		<2.3
		BEN-4			Benomyl		<0.5
8/02	Nursery #1, Azaleas/Wax Myrtle area, outdoor woody ornamental. During Benlate DF/WP application.	BIC-93	08:52 - 14:56	364	Butyl Isocyanate	<0.03	
		BAM-303			Butyl Amine	<2.8	
		BEN-6			Benomyl		<2.7
		BEN-3			Benomyl		<3.8
8/02	Nursery #1, Center of Azaleas, outdoor woody ornamental. During Benlate DF/WP application.	BIC-55	08:37 - 15:26	409	Butyl Isocyanate	<0.03	
		BAM-305			Butyl Amine	<2.2	
		BEN-8			Benomyl		<0.3
		BEN-9			Benomyl		<2.5
8/03	Nursery #2, area under bird netting, center of blueberries undergoing foliar spray. Outdoor woody ornamental.	BIC-60	08:33 - 10:59	146	Butyl Isocyanate	<0.08	
		BAM-310			Butyl Amine	<6.1	
		BEN-14			Benomyl		<6.7
		BEN-310			Benomyl		<1.3
8/03	Nursery #2, center of viburnum. Outdoor woody ornamental	BIC-62	09:05 - 11:15	130	Butyl Isocyanate	<0.09	
		BAM-311			Butyl Amine	<8.9	
		BEN-16			Benomyl		<1.3
		BEN-17			Benomyl		<7.0
8/03	Nursery #2, on plant table inside greenhouse after Benlate DF/Wp application. Greenhouse fans were off during sampling.	BIC-66	15:00 - 20:54	354	Butyl Isocyanate	0.6	
		BAM-313			Butyl Amine	<2.8	
		BEN-20			Benomyl		<2.7
		BEN-21			Benomyl		<0.5

cont'd.

8/05Weighing station - inside shed used to weigh small amounts of Benlate DF/WP.BIC-74
BAM-318
BEN-28
BEN-29
08:07 - 11:32
205Butyl Isocyanate
Butyl Amine
Benomyl
Benomyl4.0
<4.3

(8.4)
12.4

Date	Location/Description	Sample #	Sampling Period	Duration (min)	Contaminants Sampled	Concentration	
						PPB	$\mu g/m^3$
8/09	Nursery #3 - on Calathea table row, in Greenhouse	BIC-86	09:53 - 14:35	283	Butyl Isocyanate	1.0	
		BAM-329			Butyl Amine	<3.2	
		BEN-38			Benomyl		<2.3
		BEN-39			Benomyl		<0.5
8/09	Nursery #3 - middle table containing Agleonemas, in Greenhouse.	BIC-88	09:55 - 14:46	292	Butyl Isocyanate	<0.04	
		BAM-330			Butyl Amine	<3.3	
		BEN-40			Benomyl		<3.4
		BEN-41			Benomyl		<0.7
8/09	Nursery #3 - middle table containing Sphathophyllum, in Greenhouse.	BIC-91	10:00 - 15:03	303	Butyl Isocyanate	1.2	
		BAM-331			Butyl Amine	<3.5	
		BEN-42			Benomyl		<0.6
		BEN-43			Benomyl		<2.0
8/10	Nursery #4, in shadehouse area in center of petite spathophyllum. Four feet above ground	BIC-501	13:11 - 15:38	147	Butyl Isocyanate	0.5	
		BAM-336			Butyl Amine	<6.3	
		BEN-48			Benomyl		<4.2
		BEN-601			Benomyl		<1.0

cont'd.

8/10Nursery #4, in shadehouse area, center of dracena margenata. Three feet above groundBIC-502

8/13	Florida DACS Test Greenhouse, Gainesville, FL. In greenhouse adjacent plants during benlate DF application.	BIC-514	09:20 - 14:11	291	Butyl Isocyanate	0.7	
		BAM-343			Butyl Amine	<3.2	
		BEN-609			Benomyl		<0.5
		BEN-610			Benomyl		<2.2
8/13	Florida DACS Test Greenhouse, Gainesville, FL. In laboratory adjacent Benlate DF weighing and mixing area.	BIC-511	08:47 - 13:55	309	Butyl Isocyanate	1.6	
		BAM-342			Butyl Amine	<4.9	
		BEN-607			Benomyl		6.5
		BEN-608			Benomyl		<3.3

NOTE:PPB = Parts of gas or vapor per billion parts air
$\mu g/m^3$ = micrograms of contaminant per cubic meter of air sampled
() = concentration detected was between the analytical limit of detection and the level of quantification
< = less than (no contaminant detected); the concentration listed is the analytical limit of detection.
The analytical limit of detection for the contaminants sampled was:

butyl isocyanate = 0.01 microgram (µg) per sample
butyl amine = 0.3 µg per sample
benomyl = 0.2 µg per sample

Table IH-9
Area Air Sampling Results: Group B & C Nurseries
HETA 92-0381

Date	Location/Description	Sample #	Sampling Period	Duration (min)	Contaminants Sampled	Concentration	
						PPB	µg/m³
8/31	Nursery B-1, center of Greenhouse #1, on table near main aisle.	BIC-527 BAM-354 BEN-621 BEN-622	09:42 - 15:30	348	Butyl Isocyanate Butyl Amine Benomyl Benomyl	<0.02 <2.6	<0.8 <1.9
8/31	Nursery B-1, Greenhouse #1, on table off of the main aisle	BIC-526 BAM-353 BEN-619 BEN-620	09:52 - 15:15	323	Butyl Isocyanate Butyl Amine Benomyl Benomyl	<0.03 <2.9	<0.6 <2.1
8/31	Nursery B-3, Glasshouse #2, on table off of the main aisle. Roof vents closed.	BIC-528 BAM-355 BEN-623 BEN-624	08:45 - 16:23	447	Butyl Isocyanate Butyl Amine Benomyl Benomyl	<0.02 <2.2	<1.5 <0.5
8/31	Nursery B-3, Glasshouse #2, on table adjacent Dieffenbachia. Roof vents closed.	BIC-531 BAM-356 BEN-625 BEN-626	08:53 - 16:25	452	Butyl Isocyanate Butyl Amine Benomyl Benomyl	<0.02 <2.0	<0.4 <1.6
9/01	Nursery B-3, main violet greenhouse, on table in center aisle.	BIC-535 BAM-358 BEN-628 BEN-629	08:28 - 14:40	372	Butyl Isocyanate Butyl Amine Benomyl Benomyl	<0.02 <2.4	<0.6 <1.9
9/01	Nursery B-2, on table in the back of the main violet greenhouse.	BIC-537 BAM-359 BEN-630 BEN-631	08:37 - 14:54	377	Butyl Isocyanate Butyl Amine Benomyl Benomyl	<0.03 <2.5	<0.6 <2.8
9/01	Nursery C-2, on table off of the center aisle in the Fan & Pad greenhouse.	BIC-539 BAM-360 BEN-635 BEN-635	09:03 - 15:26	383	Butyl Isocyanate Butyl Amine Benomyl Benomyl	<0.02 <2.5	<0.9 <2.0
9/01	Nursery C-2, on table off center aisle in passive greenhouse.	BIC-541 BAM-361 BEN-634 BEN-635	09:16 - 15:39	303	Butyl Isocyanate Butyl Amine Benomyl Benomyl	<0.03 <2.4	<0.6 <2.7

cont'd.

Date	Location/Description	Sample #	Sampling Period	Duration (min)	Contaminants Sampled	Concentration	
						PPB	μg/m³
9/01	Nursery C-1, on table in center of open-sided greenhouse.	BIC-543 BAM-362 BEN-636 BEN-637	09:48 - 16:10	382	Butyl Isocyanate Butyl Amine Benomyl Benomyl	<0.02 <2.4	 <0.7 <4.8

NOTE:PPB = Parts of gas or vapor per billion parts air
$\mu g/m^3$ = micrograms of contaminant per cubic meter of air sampled
() = concentration detected was between the analytical limit of detection and the level of quantification
< = less than (no contaminant detected); the concentration listed is the analytical limit of detection.
The analytical limit of detection for the contaminants sampled was:

butyl isocyanate = 0.01 microgram (μg) per sample
butyl amine = 0.3 μg per sample
benomyl = 0.2 μg per sample

Table IH-10
Patch and Glove Monitoring Results: Nursery #1 and 2
Benlate DF/WP Application: August 2-3, 1993
HETA 92-0381

Worker	Activity/Application Technique	Sampling Period	Duration (min)	Total AIB applied (grams)	Concentration Benomyl (P) ($\mu g/cm^2/hr$)		Concentration Benomyl (G) ($\mu g/hr$)	
					Location	Conc.	LEFT	RIGHT
AA	Drenching Woody Ornamental Plants with Benlate DF. Used 1 and 2 pound/100 gallon concentrations. Nursery #1	07:58 - 09:55 10:00 - 11:47 13:14 - 15:36*	117 107 142	190.7 497.1 531.2	Shoulder (o) Stomach (o) Knee (o) Thigh (i)	0.03 1.72 14.1 0.06	6.7 13.3 398.9	6.1 6.1 443.7
AB	Drenching woody ornamental plants with Benlate DF and WP. Used 1, 2, 4, and 8 pounds per 100 gallons water concentrations. Nursery #1	07:57 - 10:30 10:40 - 11:48 13:15 - 15:34*	147 68 139	504.9 65.4 619.7	Shoulder (o) Stomach (o) Knee (o) Thigh (i)	ND 0.07 0.14 ND	8.0 6.0 16.4	8.2 4.7 10.3
AA	Spraying and drenching woody ornamental plants with Benlate DF and WP. Used 1, 2, and 4 pounds/100 gallons water concentrations. Nursery #2	08:09 - 10:40	151	719.6			33.0	152.0
AB	Used backpack sprayer to apply Benlate DF and WP to blueberry plants under a bird cover. Nursery # 2.	08:03 - 09:00	57	33.8	Back (i) Back (o) Thigh (i) Knee (o)	ND 1.9 ND 0.09	32.3	40.5
AB	Used low pressure/high volume system to drench woody ornamental plants with Benlate DF. Used 1 and 2 pound/100 gallon concentrations. Nursery #2	09:12 - 10:50	98	383.7			39.9	33.1
AC	Used watering can to manually drench ornamental plants with Benlate DF and WP inside a greenhouse. Used 1, 2, and 4 pound/100 gallon concentrations. Nursery #2	13:23 - 15:09	106	79.2			3.2	12.2

cont'd.

NOTE:Cotton monitor gloves were worn underneath the gloves worn by the applicators.
$\mu g/m^3$ = micrograms of contaminant per cubic meter of air sampled
$\mu g/hr$ = micrograms of benomyl detected per hour
$\mu g/cm^2/hr$ = micrograms of benomyl detected per square centimeter of patch, per hour.
Patch size was 58.1 cm^2
P = cotton gauze patch
G = cotton glove
AIB = actual grams of active ingredient (benomyl) applied.
o = patch placed outside protective clothing
i = patch placed inside protective clothing
* = time period that the patch was worn
ND = none detected (below analytical level of detection)

Table IH-11
Patch and Glove Monitoring Results: Nursery #1 - Trimming Plants
Benlate DF/WP: August 4, 1993
HETA 92-0381

Worker	Activity	Sampling Period	Duration (min)	Concentration Benomyl(P) (µg/cm²/hr)		Concentration Benomyl(G) (µg/hr-pt)	
				Location	Conc.	LEFT	RIGHT
AG	Trimming Woody Ornamental Plants that had previously (46 hours) been treated with Benlate DF and WP. Nursery #1	07:25 - 09:27	122			39.4	45.6
		09:48 - 11:25	97			30.4	34.6
AF	Trimming Woody Ornamental Plants that had previously (46 hours) been treated with Benlate DF and WP. Nursery #1	07:25 - 09:27	122			3.8	8.7
		09:49 - 11:25	96			ND	12.0
AD	Trimming Woody Ornamental Plants that had previously (46 hours) been treated with Benlate DF and WP. Nursery #1	07:25 - 09:28	123	Stomach (o) Thigh (o)	ND 0.22	84.3	17.4
		09:49 - 11:24	95	Shoulder (o) Thigh (o)	ND 0.20	13.7	17.3
AE	Trimming Woody Ornamental Plants that had previously (46 hours) been treated with Benlate DF and WP. Nursery #1	07:25 - 09:29	124	Stomach (o) Thigh (o)	ND 0.06	118.4	75.0
		09:47 - 11:25	98	Shoulder (o) Thigh (o)	ND 0.06	56.6	47.9

NOTE:No protective gloves were worn over the cotton monitor gloves.
µg/hr-pt = micrograms of benomyl detected per hour of trimming activity.
µg/cm²/hr = micrograms of benomyl detected per square centimeter of patch, per hour.
Patch size was 58.1 cm²
P = cotton gauze patch
G = cotton glove
o = patch worn outside clothing
ND = none detected (below analytical level of detection)

Table IH-12
Glove Monitoring Results: Weighing Room
Benlate DF/WP Weighing: August 5 and 9, 1993
HETA 92-0381

Worker	Activity	Sampling Period	Duration (min)	Total AIB weighed (grams)	Concentration Benomyl (µg/hr)	
					LEFT	RIGHT
AA	Weighing small (100 gram) amounts of Benlate DF/WP in enclosed portable shed, using scale and small dispense tools. August 5, 1993	08:05 - 11:27	202	4271.4	953.5	84.4
AA	Weighing small (100 gram) amounts of Benlate DF/WP in enclosed building, using scale and small dispense tools. August 9, 1993	11:03 - 11:42	39	1307	158.7	513.8

NOTE:Cotton monitor gloves were worn underneath the gloves worn by the applicators.
µg/hr = micrograms of benomyl detected per hour
AIB = actual grams of active ingredient (benomyl) weighed

Table IH-13
Patch and Glove Monitoring Results: Nursery #3
Benlate DF/WP Application: August 9, 1993
HETA 92-0381

Worker	Activity/Application Technique	Sampling Period	Duration (min)	Total AIB applied (grams)	Concentration Benomyl (P) (μg/cm²/hr)		Concentration Benomyl (G) (μg/hr)	
					Location	Conc.	LEFT	RIGHT
AB	Drenching Ornamental Plants with Benlate DF and WP inside greenhouse and shadehouse. Used 1, 2, 4, 8 pound/100 gallon concentrations.	09:44 - 12:30	166	944.3	L. Thigh (i) R. Thigh (i) L. Thigh (o) R. Thigh (o) Stomach (o)	ND ND 0.02 0.31 ND	7.4	18.6
AB	Drenching Ornamental Plants with Benlate DF and WP inside greenhouse and shadehouse. Used 1, 2, 4, 8 pound/100 gallon concentrations.	14:05 - 15:38	93	435.8	R. Knee (o) L. Knee (o)	0.17 0.07	8.4	17.2

NOTE:Cotton monitor gloves were worn underneath the gloves worn by the applicators.
μg/hr = micrograms of benomyl detected per hour
μg/cm²/hr = micrograms of benomyl detected per square centimeter of patch, per hour.
Patch size was 58.1 cm²
P = cotton gauze patch
G = cotton glove
AIB = actual grams of active ingredient (benomyl) applied.
o = patch placed outside protective clothing
i = patch placed inside protective clothing
ND = none detected (below analytical level of detection)

Table IH-14
Patch and Glove Monitoring Results: Nursery #4
Benlate DF/WP Application: August 10, 1993
HETA 92-0381

Worker	Activity/Application Technique	Sampling Period	Duration (min)	Total AIB applied (grams)	Concentration Benomyl (P) ($\mu g/cm^2/hr$)		Concentration Benomyl (G) ($\mu g/hr$)	
					Location	Conc.	LEFT	RIGHT
AA	Drenching Ornamental Plants with Benlate DF and WP inside shadehouse. Used 1, 2, 4, 8 pound/100 gallon concentrations.	13:08 - 15:09	121	872	L. Shin (o) R. Shin (o) L. Thigh (o) R. Thigh (o) Shoulder (o)	27.0 22.5 0.07 0.96 ND	241.0	157.5
AB	Assisting applicator and mixing Benlate DF and WP inside shadehouse. Moving hoses and drench machine. Mixed 1, 2, 4, 8 pound/100 gallon concentrations.	13:08 - 15:11	123	Not Applicable			77.6	123.9

NOTE:Cotton monitor gloves were worn underneath the gloves worn by the applicators.
µg/hr = micrograms of benomyl detected per hour
$\mu g/cm^2/hr$ = micrograms of benomyl detected per square centimeter of patch, per hour.
Patch size was 58.1 cm^2
P = cotton gauze patch
G = cotton glove
AIB = actual grams of active ingredient (benomyl) applied.
o = patch placed outside protective clothing
ND = none detected (below analytical level of detection)

Table IH-15
Glove Monitoring Results: Florida Department of Agriculture Test Greenhouse
Benlate DF/WP Weighing and Application: August 13, 1993
HETA 92-0381

Worker	Activity	Sampling Period	Duration (min)	Total AIB handled (grams)	Concentration Benomyl (µg/hr)	
					LEFT	RIGHT
AI	Weighing, mixing and assisting with the application of Benlate DF (1lb/100 gal.) in a greenhouse.	08:49 - 13:34	285	14	1.1	1.4
AH	Weighing, mixing, and applicating small (300-900 ml) volumes of Benlate DF (1lb/100 gal.) using a plastic syringe to drench 4" plant pots.	08:45-13:11	266	14	11.9	191.3
AJ	Weighing, mixing, and applicating small (300-900 ml) volumes of Benlate DF (1lb/100 gal.) using a plastic syringe to drench 4" plant pots.	09:12 - 13:39	267	14	ND	14.6

NOTE:Cotton monitor gloves were worn underneath the gloves worn by the applicators.
µg/hr = micrograms of benomyl detected per hour
AIB = actual grams of active ingredient (benomyl) handled
ND = none detected (below analytical level of detection)

Table IH-16
Soil Sampling Results
September 20-21, 1994
HETA 92-0381

Nursery Description	Conc. µg/gm
A-1: No Benlate Used in Area	ND
A-1: No Benlate Used in Area	ND
A-1: No Benlate Used in Area	ND
A-1	Detect
A-1	Detect
A-1	0.13
A-1	Detect
A-1	Detect
A-1	Detect
A-1	0.17
A-1	0.29
A-1	ND
A-1	ND
A-1	ND
A-1; Greenhouse	0.58
A-1; Greenhouse	0.54

Nursery Description	Conc. µg/gm
B-1; Greenhouse	0.35
B-1; Greenhouse	0.21
B-2; North Half	2.56
B-2; South Half	2.26
B-3	0.19
B-3	1.89
B-3	0.12
C-2; Pad & Fan greenhouse	ND
C-2	0.31
C-2	0.15

NOTE:µg/g = micrograms of contaminant per gram of sample
ND = not detected above the Limit of Detection (LOD) of 0.5 µg/g.
Detect = Qualitatively detected between the LOD and the Limit of Quantitation (LOQ) of 0.15 µg/g.

Table M-1
Biological Monitoring Results for 5-HBC in Urine:
Group A Sites (Current Benlate DF® Use)
HETA 92-0381

NAME	DAY	HOUR	5-HBC/ Creatinine (μmol/mol)	EXPOSURE TIME	JOB*
AA	08/02	6:15	<2.2	8:00-16:00 07/30/93	A
AA	08/02	13:00	11.9	8:00-16:00	A
AA	08/02	17:30	55.7	8:00-16:00	A
AA	08/02	21:03	70.0	8:00-16:00	A
AB	08/02	6:15	4.3	8:00-16:00 07/30/93	A
AB	08/02	13:00	7.5	8:00-16:00	A
AB	08/02	18:30	21.8	8:00-16:00	A
AB	08/02	22:00	29.6	8:00-16:00	A
AA	08/03	14:17	87.3**	7:30-11:00	A
AA	08/03	16:25	76.5	7:30-11:00	A
AA	08/03	21:10	77.4	7:30-11:00	A
AB	08/03	18:30	72.5	7:30-11:00	A
AB	08/03	21:50	87.0	7:30-11:00	A
AC	08/03	7:30	<3.4	***	A
AC	08/03	17:30	≤2.3	10:00-12:00 13:00-15:00	A
AC	08/03	21:45	≤2.4	10:00-12:00 13:00-15:00	A
AC	08/03	23:40	<6.7**	10:00-12:00 13:00-15:0	A

contd.AD0
8/04
6:30<2.2
*** C

AD	08/04	14:45	9.5	7:00-11:30	C
AD	08/04	19:30	10.6	7:00-11:30	C
AD	08/04	21:00	12.9	7:00-11:30	C
AE	08/04	5:00	<1.4	***	C
AE	08/04	14:45	15.2	7:00-11:30	C

NAME	DAY	HOUR	5-HBC/ Creatinine (µmol/mol)	EXPOSURE TIME	JOB*
AE	08/04	19:50	46.2	7:00-11:30	C
AF	08/04	6:00	<2.4	***	C
AF	08/04	16:30	1.9	7:00-11:30	C
AF	08/04	21:00	3.0	7:00-11:30	C
AG	08/04	5:50	<2.0	***	C
AG	08/04	17:35	18.9**	7:00-11:30	C
AG	08/04	20:00	11.9	7:00-11:30	C
AG	08/04	21:50	<13.4**	7:00-11:30	C
AA	08/05	6:30	8.0	7:30-11:00 08/03/93	A
AA	08/05	13:10	38.4	8:00-11:30	W
AA	08/05	18:30	55.5	8:00-11:30	W
AA	08/09	8:15	<6.7**	8:00-11:30 08/05/93	W
AA	08/09	18:25	23.8	11:00-11:45	W

cont'dAB0
8/098:20
3.97:30-
11:00
08/03/93A

AB	08/09	15:50	12.5	9:40-15:40	A
AB	08/09	20:40	18.6	9:40-15:40	A
AA	08/10	17:30	27.4	13:00-15:00	A
AA	08/10	21:26	38.6	13:00-15:00	A
AB	08/10	13:00	10.6	9:40-15:40 08/09/93	A
AB	08/10	17:30	18.9	13:00-15:00	C
AB	08/10	21:45	26.8	13:00-15:00	C
AH	08/13	6:15	<7.1**	***	A
AH	08/13	17:00	19.9	9:00-13:00	A
AH	08/13	18:00	26.3**	9:00-13:00	A
AH	08/13	21:30	37.7**	9:00-13:00	A
AI	08/13	7:30	<2.0	***	A
AI	08/13	14:55	8.3	9:00-13:00	A
AJ	08/13	8:10	<4.6	***	A

NAME	DAY	HOUR	5-HBC/ Creatinine (µmol/mol)	EXPOSURE TIME	JOB*
AJ	08/13	13:45	<4.0	9:00-13:00	A
AJ	08/13	17:00	<6.4**	9:00-13:00	A
AJ	08/13	22:00	5.8	9:00-13:00	A

* A=applying/mixing; W=Weighing; C=cutting plants/cleaning up/general nursery work
** low creatinine
*** had not applied or handled Benlate DF during past 5 days

Table M-2
Biological Monitoring Results for 5-HBC in Urine:
Group B Sites (Benlate DF® Used in Past)
HETA 92-0381

NAME	DAY	HOUR	5-HBC/ Creatinine (µmol/mol)
AK	08/31	11:00	3.4
AK	09/01	15:00	3.0
AL	08/31	8:15	<2.5
AL	09/01	11:00	<8.3*
AM	08/31	8:00	<2.7
AM	09/01	10:00	<2.8
AN	08/31	11:30	<4.0
AN	09/01	8:00	<8.3*
AO	08/31	11:00	≤1.7
AO	09/01	9:00	<3.3
AP	08/31	16:00	<2.5
AP	09/01	8:00	<3.7

cont'd.AQ08/3
111:00 3.5

AQ	09/01	8:00	1.2
AR	08/31	11:50	16.1*
AR	09/01	8:00	<2.5
AS	08/31	11:30	<3.4
AS	09/01	8:00	<12.7*
AT	08/31	13:50	<1.4
AT	09/01	8:00	<2.7
AU	08/31	11:00	<2.1
AU	09/01	8:00	<26.8*
AV	08/31	11:00	<2.4
AV	09/01	8:00	<3.4**

* low creatinine
** peak interference

Table M-3
Biological Monitoring Results for 5-HBC in Urine:
Group C Sites (Benlate DF® Never Used)
HETA 92-0381

STUDY ID	DAY	HOUR	5-HBC/ Creatinine (µmol/mol)
AW	08/31	18:00	<2.7
AW	09/01	8:00	<2.4
AX	08/31	17:00	<0.9
AX	09/01	8:00	<1.3
AY	08/31	17:00	<2.1
AY	09/01	7:00	<4.0
AZ	09/02	8:00	<1.9
AZ	09/01	11:00	<2.2
BA	08/31	17:00	<1.6
BA	09/02	12;00	<1.4
BB	09/01	17:00	<1.6
BB	09/02	11:00	<2.1
BC	09/01	18:00	<1.7
BC	09/02	8:00	<1.3
BD	09/01	17:00	<2.0
BD	09/02	12:00	<1.1
BE	09/01	17:00	<1.9
BE	09/02	12;00	<1.9