HETA 95-0248-2562
DIRTY BIRD, INC
Grady, Arkansas

Max Kiefer, CIH
Steven W. Lenhart, CIH
Randy L. Tubbs, Ph.D.
Dino Mattorano

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, technical and consultative assistance to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

Copies of this report have been sent to employee and management representatives at Dirty Bird, Inc. and the OSHA Regional Office. This report is not copyrighted and may be freely reproduced. Single copies of this report will be available for a period of three years from the date of this report. To expedite your request, include a self-addressed mailing label along with your written request to:

NIOSH Publications Office
4676 Columbia Parkway
Cincinnati, Ohio 45226
800-356-4674

After this time, copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

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

Health Hazard Evaluation Report 95-0248-2562
DIRTY BIRD, INC
Grady, Arkansas
March 1996

Max Kiefer, CIH
Steven W. Lenhart, CIH
Randy L. Tubbs, Ph.D.
Dino Mattorano

SUMMARY

On July 17-19 and August 15-16, 1995, researchers from the National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation (HHE) at Dirty Bird, Inc., an aerial pesticide application firm in Grady, Arkansas. The management request asked NIOSH to evaluate employee exposures to various pesticides during mixing, loading, and aerial application on rice or cotton. The request indicated that employees had not reported adverse health problems as a result of their potential exposures. In addition to the NIOSH HHE, Dirty Bird, Inc. was participating in an Environmental Protection Agency (EPA) sponsored project to evaluate the respiratory health effects of pesticide exposure on aerial applicators and ground crew.

During the first site visit, NIOSH investigators collected personal breathing zone (PBZ) air samples to assess ground crew (mixer-loaders) and aerial applicator (pilots) exposures to the pesticides methyl parathion, lambda-cyhalothrin (Karate®), profenofos (Curacron®), acephate (Orthene®), and cyfluthrin (Baythroid®). The potential for hand exposure with these pesticides was assessed for the three mixer-loaders, who wore cotton glove monitors underneath their protective gloves. Surface wipe samples were collected to evaluate pesticide contamination inside the cockpits and on exterior surfaces of three aircraft. Personal noise monitoring was conducted on two pilots and all three mixer-loaders.

During the followup site visit, more detailed pesticide and noise exposure monitoring was conducted, and exposure to heat stress was evaluated. PBZ, cotton glove, and patch monitoring was conducted to evaluate mixer-loader (2 workers) and aerial applicator (2 pilots) exposures to the pesticides methyl parathion, lambda-cyhalothrin, profenofos, acephate, cyfluthrin, azinphos-methyl (Guthion®), oxamyl (Vydate®), methomyl (Lannate®), and thiodicarb (Larvin®). PBZ air sampling was also conducted to assess the office administrator's exposure to pesticides. Noise dosimeters were placed on both pilots and both mixer-loaders, and spectral noise analyses were conducted to determine the dominant noise frequencies and to evaluate the flight helmets for noise attenuation. Heat stress was monitored to assess total heat loads experienced by pilots in both aircraft using the wet bulb globe temperature (WBGT) index method.

During the July 17-19, 1995, survey, methyl parathion was the only compound monitored that had a NIOSH recommended exposure limit (REL). All air sampling results were well below its 200 microgram per cubic meter ($\mu g/m^3$) REL. Glove monitoring indicated that skin exposure to pesticides was occurring, even though protective gloves were worn. The monitoring suggested that the workers' protective gloves were becoming contaminated and, when reused, resulted in additional skin exposure. The most common (and at the highest concentration) pesticide detected on the glove samples was Acephate (Orthene®). Exposure standards have not been established

for pesticides on skin or work clothes. Very low amounts of residual pesticide were detected on the surface samples collected from the aircraft. The noise monitoring showed that both pilots sampled were exposed to time-weighted average (TWA) sound levels higher than the NIOSH REL and the Occupational Safety and Health Administration (OSHA) permissible exposure limit for noise. The TWA noise exposures of the mixer-loaders also exceeded the NIOSH REL, but not the OSHA regulation.

Air sampling conducted during the August 15-16, 1995, survey showed that exposures to the pesticides sampled were low or less than detectable. All methyl parathion and azinphos-methyl (REL = 200 μg/m^3) air concentrations were well below their NIOSH RELs. As with the earlier survey, the glove monitoring showed that skin exposure was occurring, and the use of contaminated protective gloves was a possible factor. Detectable pesticide was found on patches worn on the outside of the mixer-loader's clothing, primarily on the worker's extremities (arms, legs). With one exception, all of the measured heat stress levels were below the NIOSH REL.

Inhalation exposures were low or less than detectable for the pesticides monitored during this survey. Assessment of the potential for skin exposure, however, found measurable quantities of pesticides underneath the mixer-loader's protective gloves. The results of this HHE indicate that skin contact is the primary pathway of exposure for mixer-loaders handling pesticides. Additionally, contaminated PPE is being reused without proper decontamination, resulting in additional exposure and a false sense of protection. Pilot and mixer-loader exposure to noise exceeded the NIOSH REL. (One heat stress measurement obtained inside the cockpit of an applicator's aircraft exceeded the WBGT guideline.) Recommendations are made for improving safety during the use of pesticides and for the implementation of a medical surveillance program.

TABLE OF CONTENTS

INTRODUCTION

On May 10, 1995, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) at Dirty Bird, Inc., in Grady, Arkansas. The management request asked NIOSH to evaluate exposures to pesticides during the mixing, loading, and aerial application of agricultural chemicals. Dirty Bird employees were also participating in an EPA-sponsored study to evaluate respiratory function among workers in the aerial application industry.

In response to this request, NIOSH investigators obtained additional information regarding the types of pesticides applied by Dirty Bird, Inc. and developed an exposure assessment strategy. This strategy included both inhalation and skin exposure assessments of employees during their work with pesticides, evaluation of work practices, and a review of personal protective equipment use.

On July 17-19, 1995, NIOSH investigators conducted an initial site visit at Dirty Bird, Inc. The objectives of this visit were to review the aerial application and mixing-loading process, monitor exposures to pesticides, and evaluate noise levels. On August 15-16, 1995, NIOSH investigators conducted a followup site visit to collect additional air and skin pesticide samples, evaluate noise levels, and assess heat stress in the cockpit of aircraft. Work practices and the use of personal protective equipment were also evaluated.

BACKGROUND

Dirty Bird, Inc. is an owner-operated aerial application service located in rural southeastern Arkansas. During the initial site visit, there were 7 employees (3 mixer-loaders, 1 administrator, 3 pilots, including the owner), and three aircraft were in use. During the followup site visit, two aircraft were in use and there were two mixer-loaders. Prior to being purchased in 1994 by the current owner, the aerial application service had been in business at this location for approximately 17 years. The business is operated out of a former residence that was converted into an office. A hanger and maintenance shop are connected to the office, and there is a single runway. Pesticide mixing and loading is conducted at a pesticide storage area on the concrete tarmac at the beginning of the runway, approximately 150 feet from the office. Two 500-gallon mix tanks are located under roof, adjacent to the pesticide storage room. Water tanks and fertilizer storage bins are located at this facility, as well as underground fuel tanks. Discarded pesticide containers are placed in the back of a truck and driven to a disposal site when full.

The major production crops in southeastern Arkansas are rice and cotton. Dirty Bird, Inc. serves farmers within an approximately 10-mile radius from Grady, Arkansas. Mid- to late-spring, summer, and early fall (6-7 months) are typical work seasons for aerial applicators; the off-season is generally used for aircraft maintenance. During the peak seasons, demand for service is very high, and 12-hour days, including weekend work, is not uncommon. During the hotter times of the year, most farmers request applications early in the morning to reduce evaporative loss. In addition to pesticide application, dry fertilizer is often applied. Approximately 50% of the applications during the rice season (spring, early summer) are fertilizer.

At Dirty Bird, single-engine, single seat (closed cockpit) Rockwell Thrush SR2 aircraft are used for the applications. These aircraft have high-performance 600 horsepower radial engines, and can carry up to 400 gallons of pesticide (or 2300 pounds of dry fertilizer) in a single load. Two aircraft use Pratt and Whitney (P&W) 1340 engines with a 2-blade propeller, and one aircraft uses a Polish-built PZL-3S engine with a 4-blade propeller. Most loads are delivered in 30-45 minutes, and it is unusual for an aircraft to be out for over 1-hour on any given run. Depending on the size of the field to be treated and customer application requirements, 10 or more runs may be needed to complete an application. Between trips, pilots stay in their aircraft and open one or both cockpit doors. After each trip the plane is refueled

and loaded with pesticide by the mixer-loaders. Occasionally the application "boom" under the plane may need to be changed to accommodate a different treatment rate or to install a fertilizer spreader. Communication with mixer-loaders, other pilots, and the company administrator is via a two-way radio incorporated into the pilot's Gentex Corporation HGU-33/P flight safety helmet.

In 1994, Dirty Bird Inc. installed global positioning systems (GPS) in each aircraft. These satellite-based systems allow pilots to enter coordinates for each field and can precisely guide each run. This system eliminated the need for field spotters or flaggers; therefore, it is no longer necessary to have ground crew members at each field being treated. Weather conditions must be monitored daily to ensure that wind speed and direction are appropriate for application. This is accomplished by the use of smoke bombs, dropped by the aircraft for observation. A "real-time" computerized meteorological tracking service is also used by the company.

Daily work schedules and the types of pesticides needed are difficult to predict as application needs and requirements are constantly changing. Most farmers request same-day service, or even specific times (e.g., before 9:00 a.m.) for applications. Occasionally an order may be received the previous evening, especially if it is a large application. Although some commonly used pesticides (e.g., methyl parathion) and other agricultural chemicals are stored at Dirty Bird, most farmers arrange for the pesticides to be delivered with each order. It is not uncommon for a farmer to drive to the business with a load of pesticides and request an application.

When an application order is received, the administrator calculates the mix-rate (different pesticides are often combined), volume, the number of runs necessary, and assigns a pilot. This information is written on a board at the mixing-loading station. The mixer-loaders then mix the pesticides, typically by measuring and adding the calculated amount first (using beakers or graduated cylinders), and then adding water to the tank.

Although some pesticides are dispensed from 55-gallon drums (e.g., methyl parathion), most are packaged in 1- or 5-gallon containers, or 10- to 50-pound bags.

METHODS

Air Monitoring

Personal breathing zone (PBZ) air samples were collected to determine worker exposures to organophosphate, carbamate, and pyrethroid pesticides. Calibrated air sampling pumps were placed on workers and connected via tubing to collection media located in the breathing zone. In some cases it was necessary for workers to wear two sampling pumps, as different media sets were required for certain combinations of pesticides. Monitoring was conducted for the duration of the workday, or the task of interest. After sample collection, the pumps were post-calibrated and the samples stored in a freezer until shipment. The samples were submitted by overnight delivery to the NIOSH contract laboratory (Data Chem, Salt Lake City, Utah) for analysis. Field and media blanks were submitted with the samples.

Air samples were collected using OVS-2 (OSHA Versatile Sampler) sorbent tubes at a flow rate of 1 liter per minute. The samples were desorbed and analyzed according to NIOSH fourth edition manual of analytical method 5600.[1]

Dermal Exposure

Cotton Glove Monitors

Pre-extracted sampling glove monitors made of 100% cotton were used to assess the potential for skin exposure to various pesticides during mixing and loading. The glove monitors were worn underneath the workers' protective (nitrile) gloves. Sampling time and the amount of active ingredient

(AI)[*] handled during the monitoring period were recorded for each sample set. After sampling, the glove monitors were placed in labeled amber colored jars and sealed with Teflon®-lined caps. NIOSH investigators wore protective gloves when removing the sampling glove monitors to avoid cross contamination. Left and right glove monitors were placed in separate jars for each test subject and stored in a freezer until shipment. The samples and field blanks were then shipped via overnight delivery to the NIOSH contract laboratory for analysis.

Patch and Surface Monitors

Polyurethane foam (PUF) patch monitors secured in foil-lined cardboard holders were affixed with tape and pins to the outside clothing or bare skin at various positions on the mixer-loaders to assess the potential for pesticide exposure. Locations monitored included chest, stomach, thighs, and forearms. Each patch had a collection area of 44 square centimeters (cm^2). The patches were worn for entire work shifts, and the amount of AI was noted for each pesticide handled by a worker being monitored. After each sampling period the PUF samples were removed from their holders, sealed in labeled amber jars, and placed in a freezer. The samples and field blanks were then shipped via overnight delivery to the NIOSH contract laboratory for analysis.

Surface samples were also collected with PUF monitors (without the holders). Technical grade (99%) isopropyl alcohol was used to moisten each PUF monitor prior to sampling and an approximate 100 cm^2 area was wiped for each sample. NIOSH investigators wore disposable latex gloves during sample collection, and each sample was sealed in a Teflon-lined amber jar immediately after collection.

---

[*]*Active Ingredient is the material, or component, present in a pesticide formulation responsible for killing or controlling the target pest. Pesticides are regulated primarily on the basis of active ingredients, often expressed in terms of percent, pounds per gallon, etc.*

The samples were stored in a freezer until shipment to the NIOSH contract laboratory.

Noise Monitoring

To continuously monitor noise exposures, Quest® Electronics Model M-27 Noise Logging Dosimeters were worn by employees during their work shift. The dosimeters were calibrated before and after the work shift according to the manufacturer's instructions. The dosimeters were attached to an employee's belt or the aircraft seat harness, and a small remote microphone was fastened to the work uniform (facing forward) at a mid-point between the ear and the outside of the employee's shoulder. The dosimeters were worn for an entire work day. At the end of a work shift, the dosimeters were removed and paused to stop data collection. The information stored in each dosimeter was downloaded to a personal computer with Quest® Electronics Metrosoft computer software for interpretation.

Real-time area noise sampling was conducted with a Larson-Davis Laboratory Model 2800 Real-Time Analyzer. The analyzer allows for the analysis of noise into its spectral components in a real-time mode. Octave bands over the audible frequency spectrum were sampled at the mixing area to view the frequency components of the noise impacting workers in the area. It was not possible to do spectral measurements in the air because of space limitations in the aircraft.

Heat Stress Monitoring

Area heat stress monitoring was accomplished with two Reuter-Stokes RSS 214 WibGet® monitors. This type of monitor assesses environmental heat by the Wet Bulb Globe Thermometer (WBGT) method. The WBGT is an accepted standard method for determining environmental heat stress.[2,3,4] The WBGT combines the effect of humidity, air movement, air temperature, and radiant heat into a single measurement.

Specifications provided by the manufacturer for the Reuter-Stokes RSS 214 monitor are as follows:

Accuracy: ±0.3°C
Sensor Range: 0-100°C
Sensor Response Time: <2.2 minutes (90%)
                        <4.5 minutes (95%)

The monitors were operated in the automatic logging mode and were programmed to record the measured parameters at 10-minute intervals.

WBGT measurements, in conjunction with metabolic heat production rates, can be used to estimate heat stress exposure for comparison to recommended standards. During this evaluation, metabolic heat production rates in kilocalories per hour (kcal/hr) were estimated via observation of body position and work activities and compared to standard tables. WBGT and metabolic heat rates are expressed as 1-hour time-weighted averages. These recommended standards were developed to prevent workers from exceeding a deep body (core) temperature of 38°C (100.4°F).[2,3,4,5]

The WibGet® units were placed in the cockpits of both aircraft in use on August 15, 1995, and in aircraft #3 on August 16. The monitors were placed so that there was minimal restriction of free air flow around the thermometer bulbs. Before sampling, the wick of the wet-bulb thermometer was moistened with demineralized water and the thermometer reservoir was filled. The monitors were allowed to equilibrate in each cockpit for at least 5 minutes prior to recording readings.

EVALUATION CRITERIA

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

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH recommended exposure limits (RELs)[6], (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs™)[7] and (3) the U.S. Department of Labor, OSHA permissible exposure limits (PELs)[8]. In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this

report reflect the 1971 values.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8-to-10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term. Note that the exposure limit for noise is defined as an 8-hour TWA.

Skin Exposure

Skin exposure to pesticides is often considered to be a more important portion of total exposure than inhalation.[9,10,11] Evaluation of the amount of material potentially available for absorption can provide estimates of skin exposure to contaminants. Additionally, these types of assessments are useful for evaluating the need for and efficacy of control measures, as well as personal protective equipment. 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. Exposure standards, guidelines, or recommendations by NIOSH or regulatory agencies have not been established for the concentration of the pesticides monitored on skin or work clothes.

Pesticides

The word pesticide is a broad term that refers to any substance or mixture intended to prevent, destroy, repel, or mitigate insects (insecticide, miticide, acaricide), rodents (rodenticide), nematodes (nematocide), fungi (fungicide), or weeds (herbicide), designated to be a "pest." For each type of pesticide there are numerous modes of action,

chemical classes, target organs, formulations, and physicochemical properties. Pesticide toxicity is equally diverse, and even within a similar chemical class, individual compounds ranging from extremely toxic to practically nontoxic can be found.[12] As such, generalizations about the toxicity of pesticides cannot be made without considerable qualification and explanation.

At Dirty Bird, Inc., monitoring was conducted for pesticides (all of which were insecticides) in three different chemical classes: organophosphate (profenofos, acephate, methyl parathion, azinphos-methyl); n-methyl carbamate (thiodicarb, oxamyl, methomyl); and synthetic pyrethroid (cyfluthrin, lambda-cyhalothrin). For two of these compounds, methyl parathion and azinphos-methyl, a NIOSH REL of 200 micrograms per cubic meter ($\mu g/m^3$) with a skin designation has been established.[6] The skin notation indicates that exposure by the cutaneous route contributes to overall exposure.

Organophosphate Pesticides

A variety of organophosphate chemicals are commonly used as insecticides because they are biodegradable as well as effective. Organophosphate chemicals, however, can cause adverse health effects in exposed humans through the inhibition of cholinesterase (ChE) enzymes. Symptoms after exposure to organophosphate chemicals usually appear quickly, often within a few minutes to two or three hours.[12]

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

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

The organophosphate-ChE bond is stable and largely irreversible, so recovery of ChE activity depends on the generation of new ChE. ChE inhibition, therefore, can sometimes last for months.

ChE inhibition can be measured as decreases in ChE activity. Red blood cell cholinesterase (RBC-ChE), like ChE in nerve tissues, is an A-ChE. Its rate of regeneration nearly parallels that of A-ChE in nerve tissues, making its measurement a useful method of biologically monitoring exposure to organophosphate insecticides. A significant decrease in RBC-ChE activity indicates either a recent excessive exposure or repeated exposures to amounts sufficient to depress ChE activity before recovery is complete. Other types of cholinesterase, such as plasma cholinesterase or pseudocholinesterase (P-ChE), are more sensitive to organophosphate inhibition. P-ChE activity, however, returns to baseline values earlier than RBC-ChE activity. Therefore, P-ChE values may not reflect the severity of toxicity unless blood specimens are obtained soon after exposure. P-ChE activity can also be affected by factors unrelated to organophosphate exposure, including medical conditions such as liver disease.[13] P-ChE activity is clinically useful in monitoring cases of severe organophosphate poisoning, but its use in monitoring workplace exposures is limited.

For employees with potential for occupational exposure during the manufacture and formulation of pesticides, NIOSH recommends that RBC-ChE activity be measured.[14] The range of RBC-ChE activity varies considerably among individuals who have not been exposed to organophosphate insecticides. Thus, an individual could experience a toxic decrease in RBC-ChE activity and still be within the range of values found in the general population ("normal" or reference range). For this reason, a single value within the laboratory's reference range should not necessarily be interpreted as a "normal" value. Instead, toxicity should be determined by comparing a given value with the individual's baseline value. Therefore, the NIOSH recommendations for medical monitoring of potentially exposed workers in the manufacture and formulation of pesticides include a baseline measurement of RBC-ChE activity before potential for exposure begins and periodic measurements at least annually after potential for exposure begins.[14] NIOSH recommends that measurements of periodic RBC-ChE activity be made available as frequently as once a week for employees who are potentially exposed to ChE-inhibiting insecticides.[14] The testing frequency may be initially increased to as often as every day, or, after three determinations, may be decreased to as infrequently as every eight weeks.[14] The frequency should be based on the decision of a responsible medical practitioner after consideration of the following for each employee: (1) the toxicity of the pesticides to which the employee may be exposed; (2) the potential duration and concentration of the pesticide exposure; (3) the state of health of the employee; and (4) the results of previous RBC-ChE determinations.[14]

NIOSH defines an unacceptable exposure to organophosphate insecticide as a decrease in RBC-ChE activity to below 70% of the baseline value.[14] The Biological Exposure Index (BEI) adopted by the ACGIH for exposure to organophosphate chemicals is an RBC-ChE activity equal to 70% of an individual's baseline.[2] The BEI represents the level of determinant which is most likely to be observed in specimens collected from a healthy worker who has been exposed to chemicals to the same extent as a worker with inhalation exposure to the TLV-TWA. BEIs apply to 8-hour

exposures, five days per week. ACGIH regards biological monitoring as complementary to air monitoring and not for use as a measure of adverse effects or for diagnosis of occupational illness.[2,7]

For workers without a baseline RBC-ChE value, repeated tests have been recommended after removal from exposure to determine the level at which RBC-ChE values stabilize.[15,16] RBC-ChE values, however, may continue to increase for several months after last exposure. Therefore, RBC-ChE values should not be considered baseline until they have stabilized. To ensure validity, tests should be performed by the same laboratory using the same analytic method.

The range of toxicity and potential health hazard varies widely among the four organophosphate pesticides evaluated at Dirty Bird (profenofos, acephate, methyl parathion, azinphos-methyl). The hazard associated with each is also dependent on other factors, including frequency of use, concentration, formulation, physical and chemical properties, and the efficacy of personal protective equipment against the particular compound. A brief discussion of each organophosphate evaluated is presented.

Methyl Parathion is a restricted use pesticide due to its high acute toxicity to humans and birds (restricted use means it can only be sold to or used by a certified pesticide applicator). At Dirty Bird, concentrated liquid methyl parathion (46% or 4 lbs/gallon of AI), is obtained and dispensed from either 55-gallon drums (a hand pump is used), or 5-gallon containers. Parathion use is much more prevalent during the cotton season than the rice season.

Methyl Parathion is considered to be one of the most highly toxic insecticides in use, and is classified an Environmental Protection Agency (EPA) toxicity category[*] I pesticide.[12,17,18] Because of its high

mammalian toxicity, less hazardous substitutes have become more popular; however, parathion is still extensively used in agriculture because it has a wide range of insecticidal activity and suitable physicochemical properties. Of significant concern is skin contact, as methyl parathion is rapidly absorbed through the skin and may, without symptoms, be increasingly hazardous.[19]

Azinphos-methyl (Guthion®) is also a highly toxic restricted-use pesticide with an acute oral toxicity similar to parathion, and an acute dermal toxicity somewhat lower than parathion.[20] At Dirty Bird, azinphos-methyl is dispensed as an emulsifiable liquid (22% or 2 lbs/gallon of AI) from 2.5 gallon containers. Azinphos-methyl is an EPA toxicity category I pesticide.

Profenofos (Curacron®) is an EPA toxicity category II pesticide that is used as an emulsifiable concentrate (73%, or 8 lbs/gallon of AI). At Dirty Bird, profenofos is dispensed from 2.5 gallon containers and is used primarily on cotton. As with methyl parathion and azinphos-methyl, profenofos can be absorbed through the skin and is considered a significant skin hazard, in addition to inhalation concerns. Profenofos is also a restricted-use pesticide.

Acephate (Orthene®) is a contact and systemic insecticide with a strong, pungent, sulfur-like odor. At Dirty Bird, concentrated (90% by weight) acephate is dispensed as a white powder from 20-lb bags. In addition to ChE inhibition, exposure to acephate can cause eye irritation.[21] Acephate is a non-restricted-use, EPA toxicity category III pesticide.

---

[*]The EPA has established toxicity categories for pesticides based on oral, inhalation, and dermal toxicity, and eye and skin effects. The categories

range from I (highly toxic) to IV (least toxic). These toxicity designations dictate the necessary hazard warnings on pesticide labels (e.g., danger, warning, caution, etc.).

Carbamate Pesticides

Exposure to carbamate insecticides can also cause ChE inhibition and its related symptoms. Unlike the organophosphate-ChE bond, however, the carbamate-ChE bond is rapidly broken, and carbamates are considered to be reversible ChE inhibitors. As such, the effects of carbamate exposure last for a much shorter time than that of organophosphate exposure. For this reason, biological monitoring of RBC-ChE activity may not necessarily reflect exposure to carbamate insecticides, and there is a greater span between the dose that will produce symptoms and the lethal dose.[12] As with the organophosphates, there is a wide range of acute toxicities among the carbamates. Unlike the organophosphates, however, most carbamates have low dermal toxicity and are only slightly absorbed through the skin (a notable exception to this is the pesticide aldicarb [Temik®]).[12,18] A brief discussion of each carbamate evaluated at Dirty Bird is as follows:

Oxamyl (Vydate®) is restricted-use water-soluble liquid pesticide. At Dirty Bird, oxamyl (42%, 3.77 lbs/gallon of AI) is dispensed from 2.5 gallon containers. Routes of exposure to oxamyl include inhalation as well as skin contact. Oxamyl can also cause irreversible eye damage and may be fatal if absorbed through the eyes.[22] Oxamyl is an EPA toxicity category I pesticide. DuPont, the manufacturer of Vydate® recommends an 8-hour TWA acceptable exposure limit (AEL) of $500\,\mu g/m^3$ and a 15-minute TWA of $1000\,\mu g/m^3$.[23]

Methomyl (Lannate®) is an EPA toxicity category I pesticide that is formulated as a water soluble liquid (29%, 2.4 lbs/gallon of AI) and dispensed from 2.5 gallon containers. Hazardous exposures can occur via the inhalation, dermal, and ingestion routes. As with oxamyl, methomyl can cause irreversible eye damage and can also be absorbed through the eyes.[24] Lannate is a restricted-use pesticide.

Larvin (Thiodicarb®) is an EPA toxicity category II, non-restricted-use insecticide. Thiodicarb is formulated as an aqueous flowable liquid and is dispensed from 2.5 gallon containers at Dirty Bird. Adverse health effects may occur rapidly after exposure via the inhalation, ingestion, or dermal route. Thiodicarb also may be irritating to eyes, and may cause mild skin sensitization.[25]

Synthetic Pyrethroid Pesticides

Synthetic pyrethroid insecticides are chemically similar to natural pyrethrins. Pyrethrins are the active insecticidal ingredient in pyrethrum, which is the extract of chrysanthemum flowers and one of the oldest insecticides known to man.[12,18] Synthetic pyrethroids have been modified to increase their stability in the natural environment, and make them suitable for use in agriculture.

Certain pyrethroids have been shown to be highly neurotoxic in laboratory animals when administered intravenously or orally.[18] Systemic toxicity by inhalation or dermal absorption is low, and there have been very few reports of human poisonings by pyrethroids. Very high absorbed doses could result in incoordination, tremor, salivation, vomiting, and convulsions.[18] Some pyrethroids have caused sensations described as stinging, burning, itching, and tingling - with progression to numbness, when contact with the skin occurs. Sweating and exposure to the sun can enhance this discomfort. Pyrethroids are not cholinesterase inhibitors. A brief summary of the two synthetic pyrethroids evaluated at Dirty Bird is as follows:

Cyfluthrin (Baythroid®) is a restricted-use pesticide used as an emulsifiable liquid (25%, 2lbs/gallon of AI) and dispensed from 2.5 gallon containers at Dirty Bird. Cyfluthrin can cause eye damage, and exposure can occur through both inhalation and skin contact. Cyfluthrin is an EPA toxicity category I pesticide based on the hazard to the eye. Cyfluthrin is targeted for the control of insects on cotton.

Lambda-cyhalothrin (Karate®) is also a restricted-use pesticide used as an emulsifiable concentrate (13%, 1 lb/gallon of AI) at Dirty Bird. Lambda-

cyhalothrin is a corrosive pesticide, can cause skin and eye damage, and may cause allergic skin reactions.[26] Exposure can occur via the inhalation and dermal route. Lambda-cyhalothrin is dispensed from 2.5 gallon containers at Dirty Bird, and is used during the cotton season.

Surface Contamination

Standards for surfaces contaminated with residual pesticides have not been established. Efforts to assess risks associated with residual pesticide contamination and determine "safe" levels have often involved determining the No Observable Adverse Effect Level (NOAEL), and making assumptions on skin contact, absorption, and transfer rate to estimate a potential dose received. Surface sampling can, however, provide information on the location and spread of contamination, the need for personal protective equipment, and the efficacy of housekeeping measures.

Noise

Noise-induced loss of hearing is an irreversible, sensorineural condition that progresses with exposure. Although hearing ability declines with age (presbycusis) in all populations, exposure to noise produces hearing loss greater than that resulting from the natural aging process. This noise-induced loss is caused by damage to nerve cells of the inner ear (cochlea) and, unlike some conductive hearing disorders, cannot be treated medically.[27] While loss of hearing may result from a single exposure to a very loud impulse noise or explosion, such traumatic losses are rare. In most cases, noise-induced hearing loss is insidious. Typically, it begins to develop at 4000 or 6000 Hz (the hearing range is 20 Hz to 20000 Hz) and spreads to lower and higher frequencies. Often, material impairment has occurred before the condition is clearly recognized. Such impairment is usually severe enough to permanently affect a person's ability to hear and understand speech under everyday conditions. Although the primary frequencies of human speech range from 200 Hz to 2000 Hz, research has shown

that the consonant sounds, which enable people to distinguish words such as "fish" from "fist," have still higher frequency components.[28]

The A-weighted decibel [dB(A)] is the preferred unit for measuring sound levels to assess worker noise exposures. The dB(A) scale is weighted to approximate the sensory response of the human ear to sound frequencies near the threshold of hearing. The decibel unit is dimensionless, and represents the logarithmic relationship of the measured sound pressure level to an arbitrary reference sound pressure (20 micropascals, the normal threshold of human hearing at a frequency of 1000 Hz). Decibel units are used because of the very large range of sound pressure levels which are audible to the human ear. Because the dB(A) scale is logarithmic, increases of 3 dBA, 10 dBA, and 20 dBA represent a doubling, tenfold increase, and 100-fold increase of sound energy, respectively. It should be noted that noise exposures expressed in decibels cannot be averaged by calculating a simple arithmetic mean.

The OSHA standard for occupational exposure to noise (29 CFR 1910.95) specifies a maximum PEL of 90 dB(A)-slow response for a duration of eight hours per day.[29] The regulation, in calculating the PEL, uses a 5 dB time and intensity trading relationship, or exchange rate. This means that a person may be exposed to noise levels of 95 dB(A), for no more than 4 hours, to 100 dB(A) for 2 hours, and so on. Conversely, up to 16 hours of exposure to 85 dB(A) is allowed by this exchange rate. NIOSH, in its Criteria for a Recommended Standard, proposed a recommended exposure limit of 85 dB(A) for 8 hours, 5 dB less than the OSHA standard.[30] The 1972 NIOSH criteria document also used a 5 dB time/intensity trading relationship in calculating exposure limits. However, in 1995, NIOSH changed its official recommendation for an exchange rate of 5dB to 3dB.[31] The ACGIH also changed its TLV in 1994 to a more protective 85 dB(A) for an 8-hour exposure, with the stipulation that a 3 dB exchange rate be used to calculate time-varying noise exposures.[7] Thus, a worker can be exposed to 85 dB(A) for 8 hours, but to only 88 dB(A) for 4 hours or 91 dB(A) for 2 hours.

The duration and sound level intensities can be combined to calculate a worker's daily noise dose according to the following formula:

$$Dose = 100 \times (C_1/T_1 + C_2/T_2 + ... + C_n/T_n),$$

where C_n indicates the total time of exposure at a specific noise level and T_n indicates the reference duration for that level as given in table G-16a of the OSHA noise regulation.[29] During any 24-hour period, a worker is allowed up to 100% of his daily noise dose. Doses greater than 100% are in excess of the OSHA PEL.

The OSHA regulation also has an action level of 85 dB(A), which stipulates that an employer shall administer a continuing, effective hearing conservation program when the TWA value exceeds the action level. The program must include monitoring, employee notification, observation, audiometric testing, hearing protectors, training programs, and recordkeeping. All of these requirements are included in 29 CFR 1910.95, paragraphs (c) through (o).[29]

Finally, the OSHA noise standard requires that when workers are exposed to noise levels in excess of the OSHA PEL of 90 dB(A), feasible engineering or administrative controls shall be implemented to reduce the workers' exposure levels. However, in 1983, a compliance memorandum (CPL 2-2.35) directed OSHA compliance officers to not cite employers for lack of engineering controls until workers' TWA levels exceeded 100 dB(A), so long as the company had an effective hearing conservation program in place. Even when TWA levels are in excess of 100 dB(A), compliance officers are to use their discretion in issuing fines for lack of engineering controls.

Heat Stress

Heat stress is the total net heat load on the body that results from exposure to external sources (environmental heat) and internally generated heat (metabolic heat) minus the heat lost from the body to the environment.[2,3] The environmental factors of heat stress are air temperature and movement, humidity, and radiant heat. Exposure to heat stress conditions produces physiological responses referred to as heat strain and characterized by an increase in: "core" or deep body temperature; heart rate; blood flow to the skin, and; water and salt loss due to sweating.[2] These conditions can occur when physical work is too heavy or the environment is too hot.

The body normally maintains a deep body temperature within narrow limits (about 37°C) by means of various adaptive mechanisms to either produce more heat, or rid the body of excess heat. This continuous heat regulation is an essential requirement for continued normal body function. The most important physiologic responses to heat include changes in blood flow to the skin, muscular activity, and sweating. Under excess heat conditions, blood flow to the skin increases, where heat dissipates into the environment. Muscular activity will increase if more heat is necessary (e.g., shivering), and will, if possible, decrease when less heat is needed. Sweating is a major heat dissipation mechanism that depends on the evaporation of sweat to produce a cooling effect. The rate and amount of evaporation is a function of humidity and the speed of air movement over the skin.

The major heat exchange mechanisms between the human body and the environment are convection, radiation, and evaporation.[3] Convection heat exchange (C) is the gain or loss in heat as a function of the rate of air movement over the skin and the difference in temperature between the ambient air and the skin. When the dry bulb air temperature is lower than the skin temperature (about 35°C), heat is lost from the body. When ambient temperatures exceed the skin temperature, heat is gained by convection. Radiant heat exchange (R) is the gain or loss in heat by radiation from warmer surfaces to cooler surfaces. The evaporation (E) of water (sweat) from the skin is an important cooling mechanism and always results in a net heat loss. In

hot-moist environments, evaporative heat loss may be limited by the capacity of the ambient air to accept additional moisture.

The basic equation describing heat balance is $S = M \pm C \pm R - E$, where S = the net body heat gain or loss, M = metabolic heat production, and C,R,E are described above.

Heat acclimatization is the enhanced tolerance to heat acquired by working in a hot environment.[32] The body's heat adaptive mechanisms can, through regular exposure to hot environments, significantly increase the ability to tolerate work in heat. This heat acclimatization process can usually be induced in 7-10 days of exposure to a hot environment.[3] Acclimatized workers can perform with less increase in core temperature and heart rate, and less salt loss, than unacclimatized workers.

OSHA has not promulgated regulations or standards covering heat stress, but has issued a directive to its field staff that provides technical information regarding the investigation of heat stress issues in industry.[33] This document draws heavily on NIOSH and ACGIH criteria. The NIOSH RELs and ACGIH TLVs present recommended heat exposure limits (WBGT) for a variety of work-rest regimens and worker energy costs (metabolic heat generation).[2,3] This criteria, presented in Figure 1, applies for the following conditions:
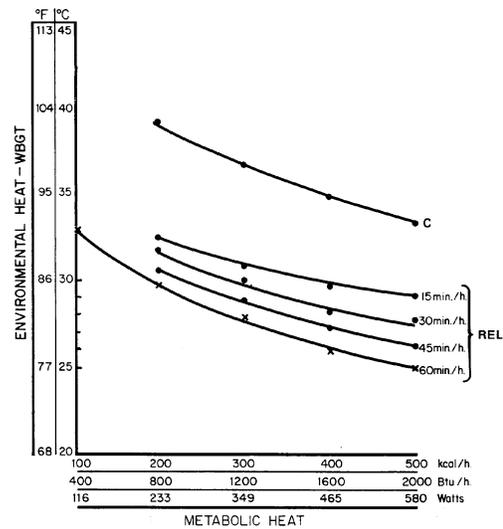
Recommended Heat-Stress Exposure Limits
Heat-Acclimatized Workers

C = Ceiling Limit
REL = Recommended Exposure Limit
*For "standard worker" of 70 kg (154 lbs) body weight and 1.8 m² (19.4 ft²) body surface.

Figure 1

a) Healthy workers who are physically and medically fit.
b) Workers who are heat-acclimatized to working in hot environments.
c) An average worker size of 154 pounds (70 kilograms).
d) Workers who are wearing light summer clothing.

If any of these parameters change, modifications must be made to the heat exposure evaluation criteria. Values are available for adjusting for worker weight and additional clothing.[3] In special cases where vapor-impermeable clothing (e.g., chemical protective suits) is worn, the WBGT is not the appropriate method for measuring environmental heat stress.

NIOSH has also established Recommended Alert Limits (RALs) for healthy workers who are not acclimatized to working in hot environments.[3] These limits are presented in Figure 2. A ceiling level has been recommended by NIOSH, for both acclimatized and un-acclimatized workers. Workers should not be exposed to temperatures reaching or exceeding this ceiling limit without adequate heat-protective clothing and equipment. These ceiling levels are indicated with a C in Figures 1 and 2.

These evaluation criteria have been established to prevent exposed workers from exceeding a deep-body or core temperature of 38°C (100.4°F). This temperature is considered to be a consensus among work physiologists and standard setting organizations as the value below which the body temperature must be maintained to reduce the risk of heat illness.[2,3,5,25]
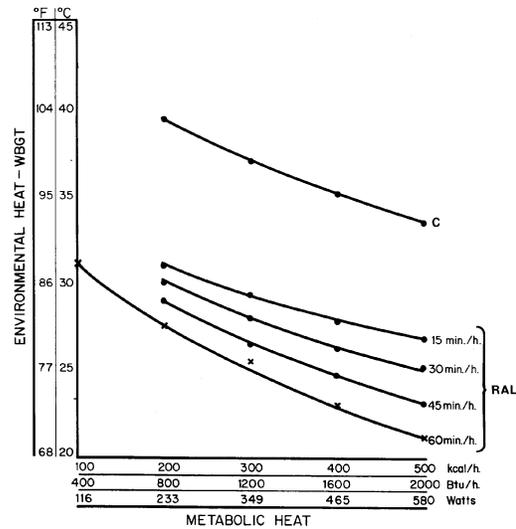
Recommended Heat-Stress Alert Limits
Heat-Unacclimatized Workers

C = Ceiling Limit
RAL = Recommended Alert Limit
*For "standard worker" of 70 kg (154 lbs) body weight and
  1.8 m² (19.4 ft²) body surface.

Figure 2

Due to the impracticality of monitoring a workers' deep body temperature, the measurement of environmental factors correlating with a workers' deep body temperature and other physiologic responses to heat is necessary. As mentioned, the WBGT is the accepted standard method for measuring these environmental factors for most situations. For outdoor use with solar loading, three measurements are needed: the natural wet bulb (nwb), the black globe temperatures (g), and the dry bulb (db) temperature. The calculation for the outdoor WBGT is as follows:

$$WBGT = 0.7t_{nwb} + 0.2t_g + 0.1_{db}$$

These measurements of environmental heat are

expressed as 1-hour TWAs.

As both metabolic and environmental heat together determine the total heat load, the work load category of each task must be established to determine the applicable heat exposure limit. For this evaluation, metabolic heat rates for each task monitored were estimated from established references (Figure 3).[2,3] This was accomplished by observation of the worker performing the task, and categorizing body position, type of work, and degree of work-rest regimen (e.g. continuous, 50%, etc.). Metabolic heat production was then estimated in kilocalories per hour (kcal/hr). The WBGT measurements, estimates of metabolic heat production (kcal/hr), and the degree of work-rest regimen were used to determine the appropriate REL for each task monitored.

Heat Stress: Health Effects

When heat gain exceeds the ability of the body to compensate through heat loss mechanisms, the core temperature will begin to rise and heat stress disorders are possible. There are a variety of outcomes that could occur, ranging from somewhat mild behavioral disorders (heat fatigue) to very severe health problems such as heat stroke. In addition to the environmental temperatures and metabolic rates, there are numerous other factors that will influence the potential for a heat related disorder to occur. These include the following:

Estimating energy cost of work by task analysis

A. Body position and movement	kcal/min*
Sitting	0.3
Standing	0.6
Walking	2.0–3.0
Walking uphill	add 0.8 per meter rise

B. Type of work	Average kcal/min	Range kcal/min
Hand work		
light	0.4	0.2–1.2
heavy	0.9	
Work one arm		
light	1.0	0.7–2.5
heavy	1.8	
Work both arms		
light	1.5	1.0–3.5
heavy	2.5	
Work whole body		
light	3.5	2.5–9.0
moderate	5.0	
heavy	7.0	
very heavy	9.0	

C. Basal metabolism	1.0

D. Sample calculation**	Average kcal/min
Assembling work with heavy hand tools	
1. Standing	0.6
2. Two-arm work	3.5
3. Basal metabolism	1.0
Total	5.1 kcal/min

* For standard worker of 70 kg body weight (154 lbs.) and 1.8 m^2 body surface (19.4 ft^2).
**Example of measuring metabolic heat production of a worker when performing initial screening.

Figure 3

1 .
Fluid intake and electrolyte replenishment.
2 .
Degree of acclimatization.
3 .
Diet.
4 .
Age.
5 .
Gender.
6 .
Body Fat.

7. Alcohol and drug (therapeutic and social) use.
8. Individual variation.
9. Physical fitness.

The primary physical disabilities caused by excessive heat exposure are, in order of increasing severity: heat rash, heat cramps, heat exhaustion, and heat stroke.[34]

Heat Rash

Heat rash ("prickly heat") occurs as a result of unrelieved exposure to humid heat with the skin continuously wet with unevaporated sweat. This often occurs when clothing traps moisture against the skin. The sweat gland ducts can become plugged which leads to inflammation of the glands. This causes profuse, visible, tiny red vesicles in the affected skin area and can substantially impair sweating. Therefore, it is not only a nuisance due to discomfort but can diminish the workers' capacity to tolerate heat.

Heat Cramps

Heat cramps can occur after prolonged exposure to heat with extensive perspiration and inadequate replacement of salt. Cramps usually occur in the abdomen and extremities.

Heat Exhaustion

Predisposing factors for heat exhaustion include sustained exertion in a hot environment, lack of acclimatization and failure to replace water and/or salt lost in sweat. These factors can result in dehydration, depletion of circulating blood volume and circulatory strain from competing demands for blood flow to the skin and active muscles. Signs and symptoms include fatigue, nausea, headache, and giddiness. There may be an increase in body temperature. The affected individual's skin will be clammy and moist.

Heat Stroke

Heat stroke is considered a serious medical emergency. A major predisposing factor is excessive physical exertion in a hot environment. Classical heatstroke includes (1) major disruption of the central nervous function (convulsions, unconsciousness); (2) a lack of sweating; and (3) a very high body temperature (>105°F). Signs and symptoms may include dizziness, nausea, severe headache, hot dry skin (due to cessation of sweating), confusion, collapse, delirium, and coma. If cooling of the victim's body is not started immediately, irreversible damage to vital organs may develop.

In addition to the above, prolonged exposure to excessive heat may cause increased irritability and anxiety, decreased morale, and an inability to concentrate. This often results in a general decrease in production efficiency and quality.[34]

RESULTS AND DISCUSSION

July 17-19 Survey

On July 17, 1995, NIOSH investigators conducted a walkthrough of the Dirty Bird facility and obtained information about the pesticide mixing, loading, and aerial application process. On July 18-19, 1995, personal breathing zone (PBZ) air sampling to assess ground crew (3 mixer-loader operators) and aerial applicator (3 pilots) exposures to the pesticides methyl parathion, lambda-cyhalothrin (Karate®), profenofos (Curacron®), acephate (Orthene®), and cyfluthrin (Baythroid®) was conducted. The potential for hand exposure to these pesticides was assessed for the three mixer-loader operators, who wore cotton glove monitors underneath their protective gloves. The amount of AI handled by the mixer-loaders during each monitoring period was determined. Surface wipe samples were collected to evaluate pesticide contamination inside the cockpit and on exterior surfaces of three aircraft. A total of 17 air, 18 glove, and 7 surface wipe samples were collected during this site visit. On July 18, noise dosimeters were placed on 2 pilots and all 3 mixer-

loaders to assess noise exposure.

During this survey, Dirty Bird, Inc. was conducting applications on both cotton and rice fields. Most pesticide applications occurred on July 18. On July 19, pesticide applications were conducted from approximately 0700 to 0830, resulting in limited sampling time. During the monitoring, the mixer-loaders wore full-length pants and long-sleeve shirts. None of the mixer-loaders wore rubber boots or shoe covers, and one mixer-loader used a rubber apron. Nitrile (flock-lined, fore-arm length) rubber gloves were worn during pesticide handling activities. Gloves were removed between mixing activities and used repeatedly. Smoking and food/beverage consumption was permitted at the mixing-loading area. Mixer-loaders ate their meals in a room adjacent to the aircraft hanger. A sink with an eyewash attachment on the faucet was available in the mixing area, but there was no safety shower.

Air Sampling

The air sampling results are shown in Table 1 (July 18) and Table 2 (July 19). Methyl parathion was the only compound monitored that has an established REL, and all results were well below the $200 \, \mu g/m^3$ limit. On July 18, the highest methyl parathion concentration ($0.7 \, \mu g/m^3$) was detected on a 93-minute sample worn by mixer-loader #2. All airborne concentrations of Karate®, Baythroid®, and Curacron® were below the analytical limit of detection during the monitoring periods, on both July 18 and July 19. Orthene® was detected on all air samples collected on July 18. Orthene® was not used on July 19. For pilots, the Orthene® concentrations ranged from $0.9 \, \mu g/m^3$ to $10.8 \, \mu g/m^3$. Orthene® concentrations ranged from $11 \, \mu g/m^3$ - $240.2 \, \mu g/m^3$ for the mixer-loaders. Sampling time was limited on July 19 as pesticide applications only occurred for approximately 1.5 hours (the remainder of the day involved fertilizer applications). Methyl parathion concentrations on July 19, however, were higher than those on the previous day; the highest concentration detected was $2.94 \, \mu g/m^3$ from mixer-loader #1.

Glove Monitoring

The glove monitoring results are shown in Table 3 (July 18) and Table 4 (July 19). As previously noted, the cotton glove monitors were worn *underneath* the mixer-loaders' protective gloves, and the amount of AI handled during the monitoring period was recorded and is shown in the tables. The results are reported in micrograms of contaminant detected over the time period the glove monitor was worn ($\mu g/hr$). On July 18, detectable levels of Larvin® were found on 8 of the 12 glove samples. The highest Larvin® concentration detected was $913.9 \, \mu g/hour$, on the right hand of mixer-loader #2. Methyl parathion was detected on 11 of the 12 glove samples on July 18; the highest concentration found was $19.4 \, \mu g/hour$ on the right hand of mixer-loader #3. On July 19, methyl parathion was detected on all 6 glove samples; the highest concentration found was $485 \, \mu g/hour$ on the left hand of mixer-loader #1. A much higher quantity of methyl parathion was handled on July 19 (81,648 grams) than July 18 (1,814 grams). Ten of the 12 samples collected on July 18 had detectable levels of Karate®, while only one sample had detectable Curacron® ($1.3 \, \mu g/hour$). However, Curacron® was not used on July 18. All samples collected on both July 18 and July 19 had detectable levels of Orthene®, with the highest concentration ($1938 \, \mu g/hour$) found on the right hand of mixer-loader #3 on July 18. Baythroid® was also detected on all samples on both monitoring days; the highest concentration detected was $281 \, \mu g/hour$, found on the right hand of mixer-loader #3 on July 18. Although detectable levels were found on all samples, Orthene® and Baythroid® were not used on July 19.

In general, higher concentrations were found on the workers' right hand gloves (all monitored workers were right-handed). Several samples, most notably Orthene®, showed detectable concentrations of contaminant even though none of the monitored pesticide was handled during the sampling period, or on the day monitored. This indicates the inside of the protective gloves are becoming contaminated, and, when reused, increases skin exposure.

Surface Monitoring

Surface wipe samples were collected to assess contamination inside the cockpit of all three aircraft, as well as residual pesticide on the exterior side of the aircraft door/windowframe. Approximately 100 square centimeters of surface area was sampled and analyzed for the pesticides used during the day of the sampling (July 18). The results, depicted in Table 5, show that residual surface contamination levels were low, and in many samples were below the analytical limit of detection.

Noise Monitoring

On July 18, noise dosimeters were placed on two pilots and three mixer-loaders for eight or more hours. The results show that on the day of the monitoring, the pilots had noise exposures higher than both the OSHA PEL and the NIOSH REL. The TWA (5-dB exchange rate) for the pilots was 102 and 103 dB(A) and the L_{eq} (equilavent level) (3-dB exchange rate) was 103 and 104 dB(A). The L_{eq} levels for the mixer-loaders were all measured at 87 dB(A) which is greater than the NIOSH REL. The noise monitoring results are shown in the following table.

Noise Monitoring Results
Dirty Bird, Inc.
July 19, 1995
HETA 95-0248

Activity Monitored	Sample Time (min)	5 dB Exchange Rate		3 dB Exchange Rate
		TWA	dose (%)	LEQ
Pilot #2, Aircraft #3: 5 hours flight time 9-cylinder P&W 1340 Engine: 600 HP	06:43-15:33 (530)	101.8	513	103.1
Pilot #1, Aircraft #3: 5 hours flight time 9-cylinder P&W 1340 Engine: 600 HP	06:53-14:56 (482)	102.6	573	104.4
Mixer-loader #2	07:06-15:05 (479)	77	17	86.9
Mixer-loader #1	06:55-1504 (488)	77.6	18	86.7
Mixer-loader #3	07:00-15:04 (484)	77.6	18	87.1

Note: All results are A-weighted.

    TWA = the accumulated noise dose, in dB(A), integrated over eight hours using a 5 dB exchange rate and a 90 dB threshold. The threshold is that sound level below which the instrument "assumes" there is no noise.

    L_{eq} = the average sound level for the actual time measured based on a 3 dB exchange rate and no threshold.

    Dose (%) = The accumulated exposure obtained, expressed in percent allowable over 8-hours.

    Peak = The highest unweighted peak level in decibels during the run time.

August 15-16, 1995, Survey

During this site visit PBZ, cotton glove, and patch monitoring was conducted to evaluate mixer-loader (2 workers) and aerial applicator (2 pilots) exposures to the pesticides methyl parathion, lambda-cyhalothrin, profenofos, acephate, cyfluthrin, azinphos-methyl (Guthion®), oxamyl (Vydate®), methomyl (Lannate®), and thiodicarb (Larvin®). PBZ sampling was also conducted to assess the Dirty Bird, Inc. office administrator's exposure to pesticides. Twenty-four air, 12 glove, and 30 patch samples were collected during this site visit. Noise dosimeters were placed on the pilots and mixer-loaders, and real-time spectral analyses were conducted to determine the dominant noise frequencies and evaluate flight helmet attenuation. Heat stress was monitored to assess total heat loads experienced by pilots in both aircraft using the wet bulb globe temperature (WBGT) index method.

The primary crop treated during this survey was cotton, and work activity was considered to be high on both sampling days. Applications began at dawn (approximately 6:30 a.m.), and work was continuous until mid-afternoon. Meals and breaks were postponed and the pilots only disembarked for short periods of time. As previously noted, there were two aircraft in operation and two mixer-loaders during this survey. On August 15, both mixer-loaders wore long sleeve shirts and long pants. One mixer-loader wore sneakers and one wore rubber boots. On August 16 one mixer-loader wore a short sleeve shirt. One mixer-loader wore a half-mask air-purifying respirator (disposable) when mixing Orthene®. However, this worker also had a beard. Both mixer-loaders wore sun-glasses. Neither mixer-loader wore hearing protection during the August survey. Both pilots wore their flight helmets and pilot #2 also used foam ear plugs.

Air Sampling

The results of the air sampling are shown in Tables 6 (August 15) and 7 (August 16). As with the air sampling conducted on July 17-18, the air concentrations detected were low or less than detectable. All methyl parathion and Guthion® concentrations were well below the NIOSH RELs for these compounds. The highest level of contaminant detected was Orthene®; a concentration of 39 µg/m^3 was found on a full-shift sample obtained from mixer-loader #1 on August 15. Low concentrations of Orthene® and methyl parathion were detected on the sample collected from the office administrator.

Glove Monitoring

The glove monitoring results are shown in Tables 8 (August 15) and 9 (August 16). On August 15, detectable levels of Baythroid® were found on 2 of the 6 glove samples; however, the worker with the detectable Baythroid® did not handle this pesticide during the sampling period. No Baythroid® was detected on August 16. Methyl parathion was detected on all glove samples on both sampling days. The highest concentration detected was 42.2 µg/hr on the right hand of mixer-loader #1 on August 15 (175 minute sample). Orthene® was detected on 6 of 6 glove samples on August 15, and 5 of 6 gloves on August 16, even though Orthene® was not used on August 16. The highest concentration detected was 836.5 µg/hr, on the right hand of mixer-loader #1 on August 15. The highest concentrations detected on August 16 were also from mixer-loader #1. Curacron® was detected on 6 of 6 samples on August 15, although this pesticide was not used during the monitoring. Five of 6 samples on August 16 had detectable levels of Curacron®; the concentrations detected on both days, however, were low (the highest concentration detected was 1.8 µg/hr on the right hand of mixer-loader #2 on August 16). Karate® was not used on either sampling day and was not found on any of the glove samples. One of 6 samples had detectable Larvin® (12.7 µg/hr) on August 15 and no Larvin® was detected on August 16. Although Lannate® was not used on either sampling day, this pesticide was found on one glove sample on August 15, and two glove samples on August 16. No Vydate® was detected on gloves obtained on August 15; Vydate® was found on 2 of 6 glove samples on August 16. Guthion® was found on 5 of 6 glove samples on August 15. The glove monitors obtained on August 16 were not analyzed for Guthion®.

As with the samples collected during the July survey, detectable concentrations of contaminant were detected on the glove samples even when the compound detected was not used during the sampling period. Orthene® again was detected at higher concentrations than any other pesticide assessed. In some cases, higher concentrations were detected on the left hand of the worker monitored. The concentrations detected varied considerably and did not seem to be related to the amount of AI handled.

Patch Monitoring

The patch monitoring results are shown in Table 10 (August 15) and Table 11 (August 16). The tables depict the concentrations detected on the PUF patch in micrograms of contaminant per square centimeter of patch, over the sampling time (hours) that the patch was worn (µg/cm^2/hr). Each patch area was 44 cm^2. All patches were worn for the duration of the workday on the *outside* of the mixer-loaders' clothing. Patches were placed in areas where the potential for exposure was considered highest from splashing or direct contact. For each sample set, the amounts of AI handled during the monitoring period were recorded.

Baythroid® was detected on 1 (right thigh) of 7 patches from mixer-loader #1 on August 15, and 4 of 7 patches from mixer-loader #2. Only mixer-loader #2 handled Baythroid® during this monitoring period. No Baythroid® was detected on patches from mixer-loader #1 on August 16, and on 3 of 9 samples from mixer-loader #2. Methyl parathion was detected on all samples from both mixer-loaders on August 15. On August 16, methyl parathion was detected on all samples from mixer-loader #2, and all but one sample from mixer-loader #1. Although Orthene® was not used on August 15,

all samples from both mixer-loaders showed detectable concentrations of this pesticide. Curacron® was detected on patch samples from both mixer-loaders on August 15, and on all patch samples from mixer-loader #2 on August 16. Curacron® was not used on August 15. Although Karate® was not used on either sampling day, this compound was detected on patches from both mixer-loaders on August 15, and on one patch from mixer-loader #1 on August 16. Larvin® was detected on one patch from mixer-loader #2 on August 15, and no samples on August 16. Lannate® and Vydate® were not detected on any patches from either mixer-loader on either day.

As with the glove monitoring, pesticides were detected on patches worn by mixer-loaders even when none of the detected pesticide was handled. Orthene® is the most notable example of this. Possible explanations include contact with contaminated equipment or material in the mixer-loader area (chairs, tables, mix tank, boom, etc.), contact with clothing or gloves that were previously contaminated, or, in the case of Orthene® (solid powder), residue from spent containers or spills become aerosolized and adhere to the patch monitors. The backdraft from the aircraft propellers creates significant turbulence in the mixer-loader area, which could resuspend previously settled dust. For those sample sets where only a few patch monitors showed detectable pesticide, most of these were on patches located in the extremities (forearm, thigh, shin). There did not appear to be a relationship between the amounts of AI handled and the concentrations of contaminants detected on the patches.

Noise Monitoring

Noise dosimetry was repeated on the two pilots and two mixer-loaders who were working during the August survey. On August 15, 1995, pilot #3 flew an aircraft that was not measured during the July survey. However, because of mechanical difficulty and a subsequent emergency landing of this aircraft on August 16, pilot #3 finished the second day in an aircraft which had been previously tested in July.

The TWA levels for pilot #2 were measured at 104 and 103 dB(A) over the two survey days, while pilot #3 was found to have TWA values of 109 and 101 dB(A). The difference in the levels for pilot #3 can be attributed to the emergency landing and change in aircraft. The mixer-loaders had noise exposures that did not exceed the OSHA PEL on either day, ranging from 74 to 82 dB(A) as a TWA. However, the NIOSH REL was exceeded both days with a range of 86 to 89 dB(A) for the L_{eq} values.

The real-time printouts from the noise dosimeters are shown in Figures 4-6. Figure 4 shows the noise exposures measured for Pilot #2 during the July and August surveys. Pilot #3 data (Figure 5) are for the August survey only as are the data for the two mixer-loaders (Figure 6). Comparison of the two pilots' data reveals a pattern of relatively steady, high intensity exposures while the aircraft are in the air. However, during landing, Pilot #2's levels remain steady until the aircraft is parked in the mixing area. Pilot #3 shows a noise increase while on the runway and just before the plane was parked; this can be attributed to this pilot's practice of opening cockpit doors while taxiing on the runway. Pilot #2 waited until the aircraft was stopped before opening the cockpit doors. An open door allows engine noise and exhaust to directly enter the cockpit.

The two different aircraft engines used in the survey produce different noise levels. This can be seen in the August 16 data for Pilot #3 during the third flight of the morning when he was forced to land the aircraft along a road next to the field being sprayed. The last four flights recorded on the noise dosimeter are in an aircraft that has a similar engine to the one flown by Pilot #2. The one aircraft used on the first three morning flights with the Polish-built PZL-3S 4-blade engine is 5 - 6 dB(A) louder in the cockpit than the Pratt & Whitney engine model. The shape of the noise spectra for the engines is also different (Figure 7). The PZL-3S engine has a predominate low frequency component with a reduction in intensity for higher frequencies. The Pratt & Whitney engine has a flatter spectrum with substantial noise intensity at the 1000 Hz octave band. Subjectively, the latter engine sounds like it has a higher pitch when the

aircraft is taking off.

The noise dosimeter data for the mixer-loaders are considerably different than the pilots data (Figure 6). Their daily noise exposure pattern is more variable, with none of the distinct plateaus seen in the pilots' noise exposures. However, there are discernable peaks in the readouts that are the result of the aircraft being on the ground for refueling and pesticide loading. The real-time analyzer measured the maximum noise exposures during take-off at 102 and 104 dB(A) in the mixing area approximately 12-15 feet behind the planes.

Neither of the mixer-loaders were observed wearing hearing protection during the August survey. The high intensity noise levels measured with the real-time analyzer point to the need for hearing protection while the aircraft are being serviced. To evaluate what type of protector to recommend, different types of devices were chosen to estimate the amount of attenuation which the mixer-loaders could expect. Two brands of semi-aural (ear canal caps) and one brand of earmuff were chosen as examples. Because of the time necessary to properly insert earplugs for an effective fit, and the cross-contamination concern of handling earplugs with potentially contaminated fingers, they are not the hearing protection device of choice. The company-provided attenuation data for a mushroom-shaped canal cap (Fleets Peace & Quiet® Headband), a bullet-shaped canal cap (Caboflex® Model 600), and an earmuff (Bilsom® UF-1) were used in calculating the adequacy of the protectors for noise exposure from aircraft take-off measured in the mixing area according to NIOSH method #1.[35] The Fleets canal caps were found to reduce the noise exposures to 87 and 89 dB(A) for the two different aircraft. The Caboflex model reduced the exposure in the protected ear to 82 and 85 dB(A), while the earmuffs reduced the noise to 78 and 80 dB(A). The attenuation data for many other types of hearing protection devices are included in a NIOSH technical report which will allow the company to compare other devices to the noise spectrum in the mixing area to select the appropriate protector.[36]

Both pilots wore Gentex® Corporation HGU-33/P flight helmets with a custom fit liner. Pilot #2 also wore E-A-R® plugs. The attenuation data for the flight helmet was obtained from a U.S. Air Force report (AMRL-TR-80-37). No spectral data were available for the cockpit when the aircraft was in flight because of space constraints. Therefore, the flight helmet's attenuation characteristics were compared to a hypothetical pink noise spectrum with each octave band equal to 100 dB. This procedure revealed that the flight helmet will provide a noise reduction rating (NRR) of only 8.3 dB.[36] A noise spectrum from the aircraft with the PZL-3S engine was obtained while the pilot increased the engine speed to 1500 RPM on the ground. The pattern of noise measured is described as having high energy in the low frequency octave bands, which is consistent with the noise data found in the mixing area for Pilot #3 (Figure 7). One can then reasonably assume that the NRR may be an overestimate of the real attenuation of noise to the pilots' ears because of the poor performance of the helmet in low frequency noise. Even when the calculated NRR value is compared to the noise dosimetry measurements for the pilots, the helmets do not offer enough protection from the noise exposures in flight. Audiometric data for one of the pilots seems to indicate prior hazardous noise exposures because of a loss of high frequency hearing when measured with pure-tone audiometry.

Heat Stress Monitoring

Table 12 depicts the results of the environmental heat stress monitoring conducted on August 15 and 16, and the corresponding RELs. As previously noted, these RELs apply to healthy, acclimatized workers wearing light summer clothing, working on a continuous basis. Additionally, these RELs are based on workers with an average body weight of 154 pounds. These results do not include any adjustments for body weight or clothing. WBGT monitoring was only conducted in aircraft #3 on August 16.

Outdoor conditions (sunny day, no cloud cover, light breeze) on the days of the monitoring were as

follows:

August 15

Time	Temperature	Relative Humidity
07:15	77 °F	85 %
10:30	91 °F	50 %
13:35	95 °F	45 %

August 16

Time	Temperature	Relative Humidity
06:45	80 °F	85 %
10:00	89	65 %

During the monitoring, the pilot #2 wore a short sleeve shirt, long pants, and a flight helmet. Pilot #3 wore a t-shirt, short pants, tennis shoes and a flight helmet. Both pilots carried water with them in the aircraft. Both aircraft were equipped with a ventilation system consisting of a intake vent located on the side of the plane and ductwork which delivers the air into the cockpit. The REL for the pilots (86 °F) was calculated from an estimated energy cost of approximately 175-200 kilocalories per hour. The WBGT levels and metabolic work rates are estimates of the heat stress burden that would be present during 60 minutes of continuous work (at the estimated work rate).

The results of the heat stress monitoring show that with one exception, all heat stress levels on the days of the sampling were below the NIOSH REL. The one exception was the 13:40-14:40 sample collected on August 15 from the cockpit of aircraft #3. A 60-minute average WBGT reading of 86.6 °F was recorded during this sampling period.

CONCLUSIONS

An evaluation to assess mixer-loader and pilot exposures to pesticides during aerial application activities found inhalation exposures to be low or less than detectable for the compounds monitored. Assessment of the potential for skin exposure, however, found measurable quantities of the pesticides sampled on cotton glove monitors worn underneath the mixer-loaders protective gloves. The results of this HHE indicate that skin contact is the primary pathway of exposure for mixer-loaders handling pesticides. Additionally, it appears that contaminated PPE is being reused without proper decontamination, resulting in additional exposure and a false sense of protection. Some of the pesticides commonly used (notably methyl parathion) are rapidly absorbed and highly toxic via the skin exposure route.

Pilot exposures to noise exceeded the NIOSH REL and OSHA PEL. The mixer-loaders exceeded the NIOSH REL on all survey days. The pattern of exposure for the ground crew measured by the dosimeter confirmed that potential noise hazards are the result of aircraft service when the engines are operating.

Except for a one-hour period, heat stress measurements showed exposure to be below the NIOSH REL. The accuracy of metabolic heat expenditure estimates made by trained observers may vary by ±10-15%, and this method of evaluation is generally viewed as a screening technique.[3] Measurement of metabolic heat (e.g., using the indirect open-circuit method) was not conducted during this evaluation.

RECOMMENDATIONS

1. Establish a comprehensive personal protective equipment (PPE) program. Elements of a good PPE program include:
• **Written procedures.** Define the necessary PPE and ensure it is properly and consistently used and maintained. The use of PPE should be mandatory.

• **Proper Selection and Use.** Note that the pesticide labels specify the necessary PPE that should be worn

by mixer-loaders. This PPE should be obtained and individually assigned. Eye and face protection during all mixing and loading activities should be part of the PPE ensemble. Gloves with absorbent liners such as cotton, leather, flock or fabric should not be used for handling or applying pesticides.

• **Inspection and Maintenance.** Mixer-loaders should be instructed how to inspect (before and after each use), use, and maintain their PPE. Chemical resistant gloves, aprons, eye protection, and footwear should be thoroughly rinsed with water at least daily and whenever contact with pesticide is suspected. Gloves should be rinsed prior to removal and discarded frequently. After cleaning, PPE should be stored properly.

It is recommended that the mixer-loader's work clothing (e.g., coveralls) be removed and left in a locker at the worksite at the end of each day. The clothing should be frequently (weekly or if known to be contaminated) laundered. PPE and work clothing should be thoroughly rinsed and separately laundered with hot water and detergent. Contaminated clothing should be immediately removed.

2. Food and beverage consumption should not be permitted at the mixing-loading area. Workers should wash their hands before eating or drinking.

3. The exposure assessment did not indicate an inhalation hazard mandating the use of respiratory protection. However, Environmental Protection Agency regulations require pesticide users to adhere to the requirements of the pesticide label, including the use of respirators. For example, the label for Vydate® requires handlers to use respiratory protection, without regard to the activity. As such, and because some workers may desire to use respirators, a respiratory protection program should be established to ensure proper respirators are selected and used properly. The respirators used by the mixer-loaders protect only against airborne particulate and were not intended for protection against pesticides. Respirator wearers must be clean shaven to ensure a tight face to facepiece seal.

4. A safety shower to allow for quick whole-body drenching in the event of an accidental contact with pesticides should be installed at the mixer-loader station.

5. Evaluate possible modifications to the mix tanks to reduce dust generation when adding solid pesticides such as Orthene® or Benlate®. A tank cover with a removable portion or section for adding pesticides is one option that should be considered. Mixer-loaders should avoid adding these materials when operating aircraft are on the tarmac.

6. Mixer-loaders should wear hearing protection when servicing aircraft to reduce exposure to high noise levels. The calculated attenuation data indicate that canal caps or earmuffs are the devices of choice. Care must be taken to assure that the hearing protection device offers enough low frequency attenuation to adequately protect the ears of the mixer-loaders when exposed to the aircraft noise. The noise results indicate that ground operations with no planes present are not loud enough to warrant the use of hearing protectors.

7. The flight helmets used by the pilots do not offer adequate protection from aircraft noise. The practice of using foam earplugs under the helmet should be required for all pilots until new helmets with sufficient attenuation, particularly in the low frequency region, are developed and purchased by the company.

8. Because it is recommended that employees wear hearing protection devices on the job, an audiometric testing program for all these employees should be instituted. The audiometric testing done on an annual basis will insure that the hearing protection devices are effective in reducing damaging noise exposures and that employees are not showing changes in their hearing acuity.

9. The practice of opening the cockpit doors shortly after landing has been shown to increase the noise levels in the aircraft. This practice should be discouraged.

10. If turning off the aircraft engine during servicing is not an option, it is recommended that the mixer-loaders fuel the planes from the trailing edge of the wing. This is a safety recommendation based on observation of this activity and the proximity of the mixer-loader to the rotating propeller during fueling.

11. Because of the potential for exposure to cholinesterase-inhibiting pesticides, a medical monitoring program for the mixer-loaders should be established. Baseline measurements of RBC-ChE activity should be obtained before exposure begins (e.g., prior to the start of the spring application season), and then made available as frequently as once a week. After three or more determinations, the frequency may be decreased. Additional monitoring should be conducted whenever there is a process change that may alter the potential for exposure.

12. Establish a heat stress management program that includes the following elements:

(a) Training of employees in safety and health procedures for work in hot environments, including the signs and symptoms of impending heat illness and initiation of first aid and/or corrective procedures. Additionally, the effects of non-occupational factors such as drugs, alcohol, obesity, etc., on tolerance to occupational heat stress should be covered. The need for fluid replenishment, and that reliance on the thirst mechanism is insufficient, are other important elements of worker heat stress training.

(b) Limiting exposure time to hot environments (e.g., scheduling hot jobs for the cooler parts of the day, altering the work-rest regimen, etc.).

(c) Ensuring all workers are fully acclimatized for working in hot environments. Acclimatization efforts should begin at the start of the hotter months of the year, and should include both new employees and employees returning from vacation or newly transferred to a hot area. Note that there is a wide difference in the ability of people to adapt to heat. In general, for workers who have had previous experience with the job, the acclimatization regimen should be exposure for 50% on day 1, 60% on day 2, 80% on day 3 and 100% on day 4. For new workers the schedule should be 20% on day 1 and a 20% increase on each additional day.

(d) Implementation of a Heat-Alert Program (HAP) for predicted hot spells. This program should be used to alert workers of impending hot spells, and initiation of heat control efforts (e.g., additional breaks, increased ventilation, shorter work cycles).

(e) Medical screening of workers to eliminate individuals with low heat tolerance. The capacity to tolerate heat has been shown to be related to physical fitness (the higher the degree of physical fitness, the greater the ability to tolerate heat) and physical work capacity (those with low physical work capacity are more likely to develop higher body temperatures than are individuals with high physical work capacity). Medical screening should also include a history of any previous heat illness. Workers who have experienced a heat illness may be less heat tolerant.

REFERENCES

1. NIOSH [1994]. Organophosphorous pesticides: method 5600. In Eller PM, Cassinelli ME, eds. NIOSH manual of analytical methods, 4th ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94-113.

2. ACGIH [1991]. Documentation of the threshold limit values and biological exposure indices, 6th. Ed. Cincinnati, Ohio: American Conference of Governmental Industrial Hygienists.

3. NIOSH [1986]. Criteria for a recommended standard: occupational exposure to hot environments (revised criteria). Cincinnati, Ohio: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control; National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 86-113.

4. International Standards Organization (ISO). Hot environments--estimation of heat stress on working man based on the WBGT index (Wet Bulb Globe Temperature). 1982; ISO 7243-1982.

5. World Health Organization. Technical Report Series No. 412, Health factors involved in working under conditions of heat stress. Geneva: WHO, 1969.

6. NIOSH. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.

7. ACGIH 1995. 1995-1996 threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

8. Code of Federal Regulations . 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

9. EPA [1986]. Pesticide assessment guidelines, subdivision U, applicator exposure monitoring. U.S. Environmental Protection Agency, Washington, DC. EPA 540/9-87-127.

10. Mull R, McCarthy J [1986]. Guidelines for conducting mixer-loader studies. Vet Hum Toxicol 28(4):328-336.

11. Leonard J, Yeary R [1990]. Exposure of workers using hand-held equipment during urban application of pesticides to trees and ornamental shrubs. Am Ind Hyg Assoc J 51(11):605-609.

12. Doull J, Klaassen C, Amdur MO, eds. [1980]. Casarett and Doull's toxicology: the basic science of poisons, 2nd Ed. New York, NY: Macmillan Publishing Company, Inc.

13. Gallo MA, Lawryk NJ [1991]. Organic phosphorus pesticides. Chapter 16. In: Hayes WJ, Jr., Laws ER, Jr, eds. Handbook of Pesticide Toxicology. Vol. 2, Classes of pesticides. San Diego, CA: Academic Press, Inc.

14. NIOSH [1978]. Criteria for a recommended standard: occupational exposure during the manufacture and formulation of pesticides. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 78-174.

15. Coye MJ, Barnett PG, Midtling JE, et al. [1986]. Clinical confirmation of organophosphate poisoning of agricultural workers. American Journal of Industrial Medicine *10*:399-409.

16. Coye MJ, Barnett PG, Midtling JE, et al. [1987]. Clinical confirmation of organophosphate poisoning by serial cholinesterase analyses. Archives of Internal Medicine *147*:438-442.

17. Sine C [1994]. Farm chemicals handbook. Vol 80. Willoughby, OH: Meister Publishing Company.

18. EPA [1989], Recognition and management of pesticide poisonings. Washington, DC: U.S. Environmental Protection Agency, Health Effects Division, Office of Pesticide Programs. EPA Publication EPA-540/9-88-001.

19. MicroFlo. Product label: methyl parathion 4EC. EPA Reg. No 51036-18. MicroFlo Company, Lakeland, FL.

20. Hathaway GJ, Proctor NH, Hughes JP, Fischman MF [1991]. Chemical hazards of the workplace, 3rd. Ed. New York: Van Nostrand Reinhold Company.

21. Valent [1994]. Product label: orthene 90S. EPA Reg No 59639-33-AA. Valent U.S.A. Corporation, Walnut Creek, CA.

22. Du Pont. Product label: vydate C-LV. EPA Reg No 352-532. E.I. du Pont de Nemours and Company, Agricultural Products, Wilmington, DE.

23. Du Pont [1990]. Vydate C-LV insecticide. Material Safety Data Sheet. E.I. du Pont de Nemours and Company, Agricultural Products, Registration and Regulatory Affairs, Wilmington, DE.

24. Du Pont [1993]. Product label: lannate LV. EPA Reg No 352-384. E.I. du Pont de Nemours and Company, Agricultural Products, Wilmington, DE

25. Rhône-Poulenc [1994]. Product label: Larvin. EPA Reg No 264-379. Rhône-Poulenc AG Company, Research Triangle Park, NC.

26. Zeneca [1994]. Product label: Karate. EPA Reg No 10182-96. Zeneca Ag Products, Wilmington, DE.

27. Ward WD [1986]. Anatomy & physiology of the ear: normal and damaged hearing. Chapter 5. In: Berger EH, Ward WD, Morrill JC, Royster LH, eds. Noise & hearing conservation manual. 4th ed. Akron, OH: American Industrial Hygiene Association, pp. 177-195.

28. Suter AH [1978]. The ability of mildly hearing-impaired individuals to discriminate speech in noise. Washington, DC: U.S. Environmental Protection Agency, Joint EPA/USAF study, EPA 550/9-78-100, AMRL-TR-78-4.

29. Code of Federal Regulations [1992]. OSHA. 29 CFR 1910.95. Washington, DC: U.S. Government Printing Office, Federal Register.

30. NIOSH [1972]. Criteria for a recommended standard: occupational exposure to noise. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Health Services and Mental Health Administration, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 73-11001.

31.   Niemeier RW [1995]. Memorandum of April 13, 1995, from R.W. Niemeier, Division of Standards Development and Technology Transfer, to NIOSH Division Directors, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Public Health Service, U.S. Department of Health and Human Services.

32.   NIOSH [1974]. The industrial environment: it's evaluation and control. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, 1973. (DHEW (NIOSH) Publication No. 74-117).

33.   U.S. Department of Labor, OSHA [1990]. OSHA Technical Manual. Chapter 3 -- heat stress. OSHA Instruction CPL 2-2.20B.

34.   NIOSH [1977]. Occupational diseases: a guide to their recognition. Revised Ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Center for Disease Control; National Institute for Occupational Safety and Health. DHEW (NIOSH) Publication No. 77-181.

35.   Kroes P, Fleming R, Lempert B [1975]. List of personal hearing protectors and attenuation data. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, National Institute for Occupational Safety and Health, HEW (NIOSH) Publication No. 76-120.

36.   Franks JR, Themann CL, Sherris C [1994]. The NIOSH compendium of hearing protection devices. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 95-105.

TABLES

Table 1
Air Sampling Results
Dirty Bird, Inc.
July 18, 1995
HETA 95-0248

Sample Description	Sample Time (minutes)	Concentration Detected: micrograms per cubic meter ($\mu g/m^3$)				
		Methyl Parathion	Karate	Curacron	Orthene	Baythroid
Pilot: Aircraft #1	08:29-11:19 (170)	0.49	NR	NR	2.7	<0.12
Mixer-loader #3	08:30-11:14 (164)	0.29	<0.05	<0.08	77.3	<0.15
Pilot: Aircraft #3	08:36-11:19 (163)	NR	<0.05	NR	0.9	<0.13
Mixer-loader #2	08:37-11:14 (157)	0.37	<0.05	NR	50.3	<0.14
Mixer-loader #1	08:43-11:14 (151)	0.26	<0.05	NR	21.8	<0.17
Pilot: Aircraft #2	10:48-11:34 (45)	0.52	<0.05	NR	5	<0.05
Mixer-loader #1	13:16-14:49 (93)	<0.06	<0.25	NR	11	<0.25
Mixer-loader #2	13:17-14:50 (93)	0.7	<0.27	NR	108.8	<0.27
Mixer-loader #3	13:18-14:48 (91)	0.33	<0.22	NR	240.2	<0.22
Pilot: Aircraft #1	13:22-15:54 (92)	NR	<0.29	NR	7.6	<0.29
Pilot: Aircraft #2	13:25-15:33 (129)	NR	<0.17	NR	10.8	<0.17
NIOSH REL		200 (skin)	NE	NE	NE	NE

NR = Analysis not requested

NE = REL not established

< Values indicate the concentration was below the analytical limit of detection

Table 2
Air Sampling Results
Dirty Bird, Inc.
July 19, 1995
HETA 95-0248

Sample Description	Sample Time (minutes)	Concentration Detected: micrograms per cubic meter ($\mu g/m^3$)		
		Methyl Parathion	Karate	Curacron
Pilot: Aircraft #3	06:50-08:05 (75)	NR	<0.1	<0.15
Pilot: Aircraft #1	06:54-08:15 (81)	1.26	NR	NR
Mixer-loader #1	07:00-08:16 (76)	2.94	NR	NR
Mixer-loader #3	07:00-08:16 (76)	1.59	NR	NR
Mixer-loader #2	07:02-08:11 (71)	1.78	NR	NR
Pilot: Aircraft #2	07:33-08:36 (63)	2.06	NR	NR
NIOSH REL		200 (skin)	NE	NE

NR = Analysis not requested

NE = REL not established

< Values indicate the concentration was below the analytical limit of detection

Table 3
Glove Monitoring Results
Dirty Bird, Inc
July 18, 1995
HETA 95-0248

Activity	Time (Minutes)	Hand Monitored	Concentration (micrograms per hour)					
			Larvin	Methyl Parathion	Karate	Curacron	Orthene	Baythroid
Fueled Aircraft, assisted with mixing/loading Mixer-loader #1	08:43-11:14 (151)	Right	ND	8.3	0.5	ND	103	1.3
		Left	ND	0.38	ND	ND	123	ND
Amount of active ingredient mixed (grams) - assisted			44054	1814	None	None	613	8700
Mixer-loader #2	08:43-11:14 (151)	Right	913.9	5.9	3.7	1.3	234	59.6
		Left	210.6	2.7	0.3	ND	30.6	13.5
Amount of active ingredient mixed (grams)			44054	1814	None	None	613	8700
Mixer-loader #3	08:54-11:14 (140)	Right	398	4.8	14.8	ND	1040	440
		Left	96	3.1	6.4	ND	300	208
Amount of active ingredient mixed (grams)			44054	1814	1361	None	613	8700
Fueled Aircraft, assisted with mixing/loading Mixer-loader #1	13:13-15:00 (107)	Right	ND	0.3	0.2	ND	224	112
		Left	ND	ND	ND	ND	95	0.6
Amount of active ingredient mixed (grams)			None	None	None	None	None	None
Mixer-loader #2	13:14-1500 (106)	Right	124.5	3	0.6	ND	224	112
		Left	79.2	0.3	0.3	ND	95	0.6
Amount of active ingredient mixed (grams)			None	None	None	None	41640	3719
Mixer-loader #3	13:15-14:51 (96)	Right	181.2	19.4	6.3	ND	1938	281
		Left	175	4	5	ND	44.4	269
Amount of active ingredient mixed (grams)			None	None	None	None	37376	3320

Table 4
Glove Monitoring Results
Dirty Bird, Inc
July 19, 1995
HETA 95-0248

Activity	Time (Minutes)	Hand Monitored	Concentration (micrograms per hour)					
			Larvin	Methyl Parathion	Karate	Curacron	Orthene	Baythroid
Fueled Aircraft, assisted with mixing/loading Mixer-loader #1	07:09-08:17 (68)	Right	30	2.5	ND	ND	114	2.1
		Left	ND	485	ND	1.1	105	1.8
Amount of active ingredient mixed (grams) - assisted			None	81648	970	27216	None	None
Mixer-loader #2	07:12-08:16 (64)	Right	10	11.2	0.3	ND	337.5	7
		Left	ND	1.2	ND	0.7	197	3.8
Amount of active ingredient mixed (grams)			None	81648	970	27216	None	None
Mixer-loader #3	07:17-08:17 (60)	Right	ND	19	24	82	940	79
		Left	ND	12	5.1	13	440	23
Amount of active ingredient mixed (grams)			None	81648	970	27216	None	None

Note: Values in parentheses indicate the concentration was between the analytical limit of detection and the limit of quantification.
ND = None Detected
Cotton Monitor gloves were worn underneath gloves worn by the mixer-loaders
Common trade names for the compounds monitored are as follows:

    Larvin = thiodicarb
    Karate = lambda cyhalothrin
    Curacron = profenofos
    Orthene = acephate
    Baythroid = cyfluthrin

Table 5
Surface Sampling Results
Dirty Bird, Inc.
July 18, 1995
HETA 95-0248

Sample Description	Concentration: micrograms per 100 square centimeters*					
	Larvin	Methyl Parathion	Karate	Curacron	Orthene	Baythroid
Joystick: Cockpit of Aircraft #1	ND	0.44	ND	ND	ND	ND
Outside Left Door Aircraft #1	ND	ND	ND	ND	ND	ND
Joystick: Cockpit of Aircraft #2	ND	ND	ND	ND	ND	ND
Left Windowsill: Aircraft #2	ND	ND	ND	ND	5.3	ND
Outside Left Door Aircraft #2	ND	ND	ND	0.62	ND	ND
Joystick: Cockpit of Aircraft #3	ND	0.5	ND	ND	ND	ND
Outside Left Door Aircraft #3	ND	ND	ND	ND	ND	ND

  * = Area sampled was approximate
ND = None detected

Table 6
Air Sampling Results
Dirty Bird, Inc.
August 15, 1995
HETA 95-0248

Sample Description	Sample Time (minutes)	Concentration Detected: micrograms per cubic meter (µg/m³)							
		Orthene	Baythroid	Karate	M. Parathion	Curacron	Larvin	Vydate	Guthion
Pilot: Aircraft #2	06:40-11:32 (292)	0.55	<0.07	<0.03	3.3	0.08	NR	NR	NR
Pilot: Aircraft #3	06:41-14:09 (448)	1.79	<0.04	<0.02	3.1	0.12	NR	NR	<1.8
Mixer-loader #1	06:44-13:28 (406)	39.4	<0.05	<0.02	2.4	0.05	NR	NR	<2.0
Mixer-loader #2	06:44-10:55 (253)	5.9	<0.08	<0.04	3	<0.01	NR	NR	NR
Administrator	07:13-14:50 (250)	1.3	<0.04	<0.02	0.5	<0.01	NR	NR	<1.8
Mixer-loader #1	09:05-13:28 (263)	NR	NR	NR	NR	NR	<8.0	<12.0	NR
Pilot: Aircraft #3	09:43-14:08 (265)	NR	NR	NR	NR	NR	<4.2	<6.3	NR
Mixer-loader #2	10:55-14:37 (222)	NR	NR	NR	NR	NR	<9.6	<14.4	NR
Mixer-loader #2	10:56-14:37 (221)	1.29	<0.1	<0.04	3.6	0.1	NR	NR	NR
Pilot: Aircraft #2	11:32-13:22 (110)	<0.04	<0.18	<0.06	3.1	<0.03	NR	NR	NR
Pilot: Aircraft #2	11:32-14:53 (201)	NR	NR	NR	NR	NR	<10	<15	NR
Pilot: Aircraft #2	13:20-14:53 (92)	<0.4	<0.2	<0.07	3.4	<0.03	NR	NR	NR
NIOSH REL		NE	NE	NE	200 (skin)	NE	NE	NE	200 (skin)

NR = Analysis not requested
NE = REL not established

Common chemical names for the compounds monitored are as follows:

Larvin = thiodicarb   **Karate = lambda cyhalothrin**   **Curacron = profenofos**
Orthene = acephate   **Baythroid = cyfluthrin**   **Vydate = oxamyl**
Guthion = azinphos-methyl

Table 7
Air Sampling Results
Dirty Bird, Inc.
August 16, 1995
HETA 95-0248

Sample Description	Sample Time (minutes)	Concentration Detected: micrograms per cubic meter ($\mu g/m^3$)						
		Orthene	Baythroid	Karate	M. Parathion	Curacron	Larvin	Vydate
Pilot: Aircraft #2	08:24-13:01 (277)	NR	NR	NR	NR	NR	<7.4	<11.0
Pilot: Aircraft #3	06:43-08:27 (104)	NR	NR	NR	NR	NR	<19.6	<29.4
Pilot: Aircraft #3	06:43-08:27 (104)	<0.04	<0.19	<0.09	2.5	0.11	NR	NR
Mixer-loader #1	06:37-08:50 (133)	NR	NR	NR	NR	NR	<15	<22.6
Pilot: Aircraft #2	08:24-11:19 (175)	<0.24	<0.12	<0.05	1.6	0.14	NR	NR
Mixer-loader#1	06:37-08:51 (134)	11.3	<0.15	<0.07	1.7	<0.02	NR	NR
Mixer-loader #2	07:38-11:38 (244)	0.7	<0.08	<0.04	2.3	0.49	NR	NR
Mixer-loader #2	07:38-11:40(242)	NR	NR	NR	NR	NR	<8	<12
Mixer-loader #1	10:24-11:32 (68)	1.5	<0.3	<0.13	2.2	0.34	NR	NR
Mixer-loader #1	10:24-11:32 (68)	NR	NR	NR	NR	NR	<29	<44
Pilot: Aircraft #3	10:16-12:38 (132)	<0.31	<0.15	<0.07	1.76	<0.02	NR	NR
Pilot: Aircraft #2	10:16-12:39 (133)	NR	NR	NR	NR	NR	<15	<23
NIOSH REL		NE	NE	NE	200 (skin)	NE	NE	NE

< Values indicate the concentration was below the analytical limit of detection
NR = Analysis not requested
NE = REL not established

Common chemical names for the compounds monitored are as follows:
Larvin = thiodicarb **Karate = lambda cyhalothrin** **Curacron = profenofos**
Orthene = acephate **Baythroid = cyfluthrin** **Vydate = oxamyl**
Guthion = azinphos-methyl

Table 8
Glove Monitoring Results
Dirty Bird, Inc
August 15, 1995
HETA 95-0248

Activity	Time (Minutes)	Hand Monitored	Concentration (micrograms per hour)								
			Baythroid	Methyl Parathion	Orthene	Curacron	Karate	Larvin	Lannate	Vydate	Guthion
Mixer-loader #1	06:59-10:27 (208)	Right	2.5	26.5	836.5	0.4	ND	ND	ND	ND	5.8
		Left	1.5	31.7	461.5	0.3	ND	12.7	12.7	ND	5.8
Amount of Active Ingredient mixed (grams)			None	6465	41028	None	None	30843	None	None	40992
Mixer-loader #1	10:35-13:30 (185)	Right	ND	42.2	314.6	0.3	ND	ND	ND	ND	9.7
		Left	ND	4.5	301.6	0.1	ND	ND	ND	ND	9.7
Amount of Active Ingredient mixed (grams)			None	None	None	None	None	61506	None	None	38441
Mixer-loader #2	07:08-14:38 (450)	Right	ND	9.1	54.7	1.7	ND	ND	ND	ND	2.7
		Left	ND	3.5	46.7	0.2	ND	ND	ND	ND	ND
Amount of active ingredient mixed (grams)			6124	5797	None	None	None	62561	None	None	None

ND = None Detected
Cotton Monitor gloves were worn underneath gloves worn by the mixer-loaders
Common chemical names for the compounds monitored are as follows

Larvin = thiodicarb
Karate = lambda cyhalothrin
Curacron = profenofos
Orthene = acephate
Baythroid = cyfluthrin

Guthion = azinphos-methyl
Lannate = methomyl
Vydate = oxamyl

Table 9
Glove Monitoring Results
Dirty Bird, Inc
August 16, 1995
HETA 95-0248

Activity	Time (Minutes)	Hand Monitored	Concentration (micrograms per hour)							
			Baythroid	Methyl Parathion	Orthene	Curacron	Karate	Larvin	Lannate	Vydate
Mixer-loader #1	06:50-08:50 (120)	Right	ND	31	385	0.4	ND	ND	55	ND
		Left	ND	25	800	ND	ND	ND	85	ND
Amount of Active Ingredient mixed (grams)			None	37395	None	None	None	None	None	26283
Mixer-loader #1	10:24-11:34 (70)	Right	ND	5.7	369	1.5	ND	ND	ND	85.7
		Left	ND	18.9	197	5	ND	ND	ND	85.7
Amount of Active Ingredient mixed (grams)			None	14515	None	None	None	None	None	2736
Mixer-loader #2	07:00-11:40 (280)	Right	ND	10.7	28	1.8	ND	ND	ND	ND
		Left	ND	1.7	ND	0.7	ND	ND	ND	ND
Amount of active ingredient mixed (grams)			1270	21772	None	18507	None	None	None	15237

ND = None Detected
Cotton Monitor gloves were worn underneath gloves worn by the mixer-loaders
Common chemical names for the compounds monitored are as follows

Larvin = thiodicarb
Karate = lambda cyhalothrin
Curacron = profenofos
Orthene = acephate
Baythroid = cyfluthrin

Guthion = azinphos-methyl
Lannate = methomyl
Vydate = oxamyl

Table 10
Patch Monitoring Results
Dirty Bird, Inc
August 15, 1995
HETA 95-0248

Activity	Time (Minutes)	Patch Location	Concentration (µg/cm^2/hr)							
			Baythroid	M. Parathion	Orthene	Curacron	Karate	Larvin	Lannate	Vydate
Mixer-loader #1	06:56-13:40 (404)	Stomach	ND	0.16	0.11	ND	ND	ND	ND	ND
		L. Chest	ND	0.16	0.1	ND	ND	ND	ND	ND
		R. Chest	ND	0.01	0.12	ND	ND	ND	ND	ND
		R. Thigh	0.01	0.24	0.71	0.002	0.001	ND	ND	ND
		L. Thigh	ND	0.84	0.22	0.001	ND	ND	ND	ND
		R. Forearm	ND	0.02	0.31	ND	ND	ND	ND	ND
		L. Forearm	ND	0.02	0.31	ND	ND	ND	ND	ND
Amount of Active Ingredient mixed (grams)			None	6465	41028	None	None	92349	None	None
Mixer-loader #2	07:05-14:41 (456)	Stomach	ND	0.02	0.03	ND	ND	ND	ND	ND
		L. Chest	ND	0.01	0.03	ND	ND	ND	ND	ND
		R. Chest	ND	0.01	0.02	ND	ND	ND	ND	ND
		R. Thigh	0.01	0.04	0.08	0.001	ND	ND	ND	ND
		L. Thigh	0.08	0.17	0.36	0.05	0.003	0.54	ND	ND
		R. Forearm	0.01	2.5	0.07	0.01	0.001	ND	ND	ND
		L. Forearm	0.005	0.05	0.02	ND	ND	ND	ND	ND
Amount of Active Ingredient mixed (grams)			6124	5797	None	None	None	62561	None	None

ND = None Detected
Polyurethane foam patches were worn outside the workers clothing
µg/cm^2/hr = micrograms of contaminant detected per square centimeter of patch, per hour
Patch size was 44 cm^2
Common chemical names for the compounds monitored are as follows:

Larvin = thiodicarb
Karate = lambda cyhalothrin
Curacron = profenofos
Orthene = acephate

Guthion = azinphos-methyl
Lannate = methomyl
Vydate = oxamyl
Baythroid = cyfluthrin

Table 11
Patch Monitoring Results
Dirty Bird, Inc
August 16, 1995
HETA 95-0248

Activity	Time (Minutes)	Patch Location	Concentration (µg/cm²/hr)							
			Baythroid	Methyl Parathion	Orthene	Curacron	Karate	Larvin	Lannate	Vydate
Mixer-loader #1	06:58-11:38 (280)	Stomach	ND	0.03	0.05	0.004	ND	ND	ND	ND
		L. Chest	ND	0.005	0.02	ND	ND	ND	ND	ND
		R. Chest	ND	0.003	0.02	ND	ND	ND	ND	ND
		R. Thigh	ND	ND	0.11	0.002	ND	ND	ND	ND
		L. Thigh	ND	0.13	0.73	0.001	ND	ND	ND	ND
		R. Forearm	ND	0.02	0.06	ND	0.001	ND	ND	ND
		L. Forearm	ND	0.03	0.05	ND	ND	ND	ND	ND
Amount of Active Ingredient mixed (grams)			None	51910	None	None	None	None	None	29019
Mixer-loader #2	07:00-11:42 (282)	Stomach	0.006	0.006	0.04	0.002	ND	ND	ND	ND
		L. Chest	ND	0.005	ND	0.002	ND	ND	ND	ND
		R. Chest	ND	0.006	ND	0.003	ND	ND	ND	ND
		R. Thigh	ND	0.01	0.03	0.002	ND	ND	ND	ND
		L. Thigh	0.02	0.05	0.05	0.006	ND	ND	ND	ND
		R. Forearm	ND	0.04	0.02	0.004	ND	ND	ND	ND
		L. Forearm	ND	0.01	ND	0.005	ND	ND	ND	ND
		R. Shin	0.01	0.03	0.01	0.004	ND	ND	ND	ND
		L. Shin	ND	0.01	ND	0.003	ND	ND	ND	ND
Amount of Active Ingredient mixed (grams)			1270	21772	None	18507	None	None	None	15237

Note: Values in parentheses indicate the concentration was between the analytical limit of detection and the limit of quantification.
ND = None Detected
Polyurethane foam patches were worn outside the workers clothing
µg/cm²/hr = micrograms of contaminant detected per square centimeter of patch, per hour
Patch size was 44 cm²

Table 12
Heat Stress Measurements
Dirty Bird, Inc
August 15-16, 1995
HETA 95-0248

Activity Monitored/Date	Time	WBGT/TWA[1]	REL[2]
Cockpit, Aircraft #3, August 15	7:40-8:40	76.2	86
	8:40-9:40	77.5	
	9:40-10:40	78.4	
	10:40-11:40	83.1	
	11:40-12:40	80.5	
	12:40-13:40	81.8	
	13:40-14:20	86.6	
Cockpit, Aircraft #2, August 15	7:10-8:10	77.5	86
	8:10-9:10	79.5	
	9:10-10:10	81.5	
Cockpit, Aircraft #3, August 16	6:20-7:20	74.2	86
	7:20-8:20	78.2	
	10:10-11:10	82.1	
	11:10-12:10	83.1	
	12:10-12:40	84.1	

1)   WBGT = Wet Bulb Globe Thermometer/Time-Weighted Average in degrees fahrenheit. These are approximately hourly TWAs based on a series of 10-minute integrated measurements recorded by the WibGet®.

The WBGT measurement is, for outdoor conditions with solar load, a combination of the natural wet bulb (NWB) temperature, the globe temperature (GT) , and the dry bulb temperature (DB). The WBGT is calculated as follows: WBGT (outdoor) = 0.7NWB + 0.2GT + 0.1DB.

This measurement incorporates the environmental factors of air temperature and movement, humidity, and radiant heat

2)   REL = NIOSH Recommended Exposure Limits to heat stress for acclimatized workers. These RELs are determined from a combination of WBGT environmental measurements and estimates of worker energy costs (metabolic heat generation). These RELs apply for the following conditions:

a) acclimatized, healthy workers
b) average worker size of 154 lbs (70 kilograms)
C) a continuous work regimen
d) workers wearing light summer clothing