# Evaluation of Occupational Exposures at an Insect Rearing Facility

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## Contents



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The cover photo is a close-up image of sorbent tubes, which are used by the HHE Program to measure airborne exposures. This photo is an artistic representation that may not be related to this Health Hazard Evaluation. Photo by NIOSH.

# Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from a federal agency on behalf of employees who worked at an insect rearing facility. Managers and employees were concerned about potential exposures to chemicals such as formaldehyde and bleach, insects, insect debris, and overall indoor environmental quality at the facility.

## What We Did

- We visited the facility in November 2009, May 2010, and August 2010.
- We interviewed employees about their work, their health, and their concerns.
- We reviewed health questionnaire results and lung function testing done by a contractor hired by the employer.
- We took personal air samples to measure employees' exposures to particulates.
- We took area air samples to look for moth scales and other insect debris.
- We took personal and area air samples for formaldehyde during egg preparation and disinfection.
- We observed engineering controls, ventilation, work practices, and personal protective equipment use.

We evaluated employees' exposures to formaldehyde and inhalable particulate matter in the insect rearing facility. Employees' exposures to formaldehyde in the egg preparation area were above occupational exposure limits. Inhalable particulate exposures from insect debris were highest during moth collection and tray scraping. Some employees reported health symptoms and had medical evidence that suggested potential allergy, occupational asthma and lung obstruction. We recommended modifying the ventilation systems to improve capture and removal of inhalable particulates containing allergens and irritants.

## What We Found

- Employee exposures to formaldehyde during egg preparation and disinfection were above occupational exposure limits.
- Work procedures and practices could increase the potential for formaldehyde in the air and skin exposure to formaldehyde.
- Employees' exposures to airborne particulates were low, except during moth pouring, work in the egg production room, and tray scraping.
- Local exhaust ventilation in the egg production room, during moth pouring, and during tray scraping was not effective.
- Employees reported health symptoms that could be caused by exposure to workplace allergens such as insects, insect debris, moth scales, chemicals, insect diet ingredients, and latex gloves.

- Some employees had changes on their lung function tests that suggested occupational asthma and lung obstruction.

## What the Employer Can Do

- Improve the performance of the lab hood and procedures during egg preparation and disinfection to reduce airborne formaldehyde exposures.
- Raise the platform for employees who place egg rings in formaldehyde tanks.
- Improve the local exhaust ventilation in egg production and during moth pouring and tray scraping.
- Ensure employees consistently use personal protective equipment.
- Replace latex gloves with nitrile gloves to eliminate a potential allergen source.

## What Employees Can Do

- Carefully handle and pour ingredients from bags to minimize dust exposures.
- Use a vacuum with high efficiency particulate air filters instead of compressed air to clean work areas, clothing, or personal protective equipment.
- Always wear personal protective equipment that is advised or recommended for your work area.
- Tell your supervisor and your doctor if you have health concerns you think are related to work.
- Participate in all training about workplace hazards and respirator fit testing.

# Abbreviations

| | |
|---|---|
| ACGIH® | American Conference of Governmental Industrial Hygienists |
| CFR | Code of Federal Regulations |
| $CO_2$ | Carbon dioxide |
| FOH | Federal Occupational Health |
| $FEV_1$ | Forced expiratory volume in one second |
| fpm | Feet per minute |
| FVC | Forced vital capacity |
| HVAC | Heating, ventilation, and air-conditioning |
| IOM | Institute of Medicine |
| LEV | Local exhaust ventilation |
| $mg/m^3$ | Milligrams per cubic meter |
| NAICS | North American Industry Classification System |
| NIOSH | National Institute for Occupational Safety and Health |
| OEL | Occupational exposure limit |
| OSHA | Occupational Safety and Health Administration |
| PBWRF | Pink bollworm rearing facility |
| PEL | Permissible exposure limit |
| PPE | Personal protective equipment |
| ppm | Parts per million |
| REL | Recommended exposure limit |
| TLV® | Threshold limit value |
| TWA | Time-weighted average |

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# Introduction

The Health Hazard Evaluation Program received a request from the United States Department of Agriculture (USDA) on behalf of employees who worked at a pink bollworm rearing facility (PBWRF). Managers and employees were concerned about indoor environmental quality and possible development of respiratory problems and allergies from exposures to chemicals, insects, and insect debris. We visited the PBWRF in November 2009, May 2010, and August 2010 to evaluate employee exposures and learn more about health concerns. We sent union representatives, Federal Occupational Health (FOH) representatives, and PBWRF managers an interim letter in December 2009 that summarized our findings and recommendations. The PBWRF sent us a copy of its action plan to address our initial findings in December 2009. This report summarizes our findings and recommendations based on the conditions at the time of our evaluation.

# Background and Process Description

The PBWRF raised a single species of moth, *Pectinophoa gossypiella* (pink bollworm). Moths and butterflies belong to the insect order Lepidoptera. Species in this order have been associated with contact dermatitis, urticaria, and respiratory irritation and asthma in occupational and non-occupational settings [Centers for Disease Control and Prevention 1984; Redd et al. 2007; Suarthana et al. 2012]. The moths reared at this facility were sterilized by irradiating them with cobalt 60. Sterile moths were subsequently released from aircraft into cotton fields as the Sterile Insect Technique component of the International Pink Bollworm Eradication Program. Additional information on the pink bollworm eradication program can be found at http://www.cdfa.ca.gov/plant/ipc/pinkbollworm/pbw_hp.htm.

At the time of our evaluation the facility was staffed by 25 employees year-round and an additional 47 seasonal employees. The seasonal employees typically worked from March to October to coincide with the increased need for moths during the cotton growing season. At the time of our evaluation between 20 and 26 million moths were produced daily during the cotton growing season; the facility was designed to produce approximately 15 million moths daily. Smaller numbers of moths (approximately 300,000 per day) were reared during the off season to maintain a continuous supply of bollworms on the basis of the lifecycle shown in Figure 1.

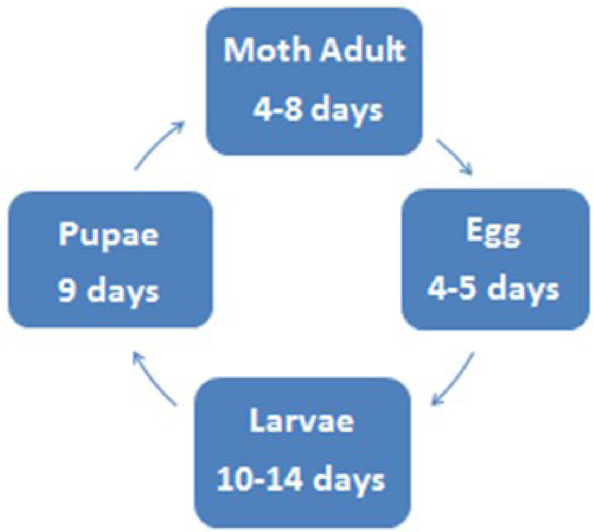


Figure 1. The 25 to 35 day life cycle of the pink bollworm. Figure by NIOSH.

Moth production was divided into two areas: “dirty” and “clean.” The dirty area refers to the part of the PBWRF where scales from moth wings (moth scales) were released during operations. The dirty area was maintained under negative pressure relative to surrounding areas to contain moth scales. The clean area refers to locations within the PBWRF where adult moths and scales should not be found. This arrangement was necessary to protect the health of the moth colony and ensure adequate moth production. Adult moths and scales can contain pathogens that can infect the other bollworm life stages and lead to death and decreased production. The facility had detailed sanitation and pest management protocols to address this concern. Floor to roof fire walls separated the administrative office area from the adjacent clean moth production area. The facility did not have a plenum or air exchange between the administrative office and production areas.

Table 1 summarizes work processes and work areas within insect production and insect production support. A detailed description of the work areas is found in Appendix B. “Mandatory” and “advised” personal protective equipment (PPE) requirements varied by work location and are summarized in Appendix C.

Table 1. Work processes and work areas within insect production and insect support

| Insect production | Insect production support |
|---|---|
| Egg preparation | Diet weight room |
| Egg infestation | Kitchen |
| Dark room | Hexcel cleaning |
| Cutout room | Cardboard cleaning |
| Hexcel® stripping | Tray scraping |
| Egg production | Quality control |
| Moth production and collection | Maintenance |
| Moth irradiation | Supervisor |
| Moth packaging and shipping | |

# Methods

The objectives for this evaluation were the following:

1. Measure airborne exposures to formaldehyde and inhalable particulates.
2. Identify whether insect debris was present in air samples.
3. Evaluate engineering controls, work practices, and PPE use during moth production.
4. Identify potential work-related employee health concerns.
5. Determine if employees had changes in lung function that could be related to work.

## Formaldehyde

In May 2010, we collected task-based personal air samples for formaldehyde on two employees disinfecting insect eggs. We collected one area air sample for formaldehyde in each of the two egg preparation rooms where egg rings were immersed in open tanks that contained 54 gallons of 9% formaldehyde. Air samples were collected and analyzed according to National Institute for Occupational Safety and Health (NIOSH) Method 2016 [NIOSH 2016].

## Inhalable Particulate Matter

In August 2010, we collected task-based or partial shift inhalable particulate air samples on employees during potentially dust-generating work activities in the insect diet weight room, kitchen, Hexcel stripping room, south cutout room, north cutout room, moth collection coolers or rooms, egg production room, moth packing and shipping rooms, irradiation room, and tray scraping room. Inhalable particulate matter comprises particles that are hazardous when deposited anywhere in the respiratory tract. The 50% cut point for inhalable particulate matter is 100 micrometers aerodynamic diameter [ACGIH 2017]. The samples were collected on Institute of Medicine (IOM) samplers with polyvinyl chloride filters and analyzed gravimetrically according to NIOSH Method 0600 [NIOSH 2016]. We had conducted similar personal sampling for inhalable particulate matter in May 2010; however, due to laboratory errors (e.g., negative weight gain of samples) the sample results were rejected and not reported.

## Scanning Electron Microscopy

We collected nine area air samples in May 2010 for analysis by scanning electron microscopy to identify whether insect debris was present during potentially dust-generating work activities. These samples were collected in the same locations where we also collected the inhalable particulate matter personal samples, except for the Hexcel stripping room and irradiation room. The area samples were collected on three-piece air sampling cassettes containing 0.8-micrometer pore size polycarbonate filters at a flow rate of 2 liters per minute. Portions of each air sample filter and a bulk sample of moth scales and insect debris were placed onto carbon-taped stubs and then carbon coated. A Tescan scanning electron microscope equipped with a Gresham light element energy dispersive spectrometer and an IXS digital imaging system was used to examine the air sample filter and bulk samples. Photomicrographs were also taken of each sample.

## Local Exhaust Ventilation and Carbon Dioxide Measurements

We measured air velocities at the face of local exhaust ventilation (LEV) hoods using a TSI® Velocicalc Plus® at operations where we observed that airborne dust capture appeared to be insufficient. These operations included diet weighing, kitchen, Hexcel sheet stripping, moth pouring/collection, packing, and tray scraping. On the basis of the hood face velocities and the distance from the hood that work activities were done, we estimated capture velocities. We used a TSI Q-Trak® to take spot check measurements of carbon dioxide levels in the facility.

## Medical Evaluation

We held confidential medical interviews with full-time employees in November 2009 at the end of the production season to discuss their work practices and health concerns. On the basis of our initial findings and observations, we returned in May 2010 to further evaluate employee health. During this visit we worked with an FOH physician who provided medical services for facility employees. FOH personnel held an in-service training with employees about potential workplace hazards and the spirometry (lung function testing) process. FOH personnel administered a brief questionnaire in English or Spanish based on the employees' personal preference to determine if they were medically qualified for spirometry participation. FOH did preshift and postshift spirometry on consenting full-time and seasonal production workers. The NIOSH investigator and FOH physician developed a brief questionnaire in English and Spanish on job duties and health symptoms; FOH personnel administered this questionnaire after spirometry was completed. FOH personnel repeated the spirometry questionnaire and spirometry in September 2010. FOH provided spirometry results and interpretation by letter in English and Spanish to individual participants in November 2010. FOH provided a summary of spirometry and questionnaire results and interpretation to facility managers and federal agency health and safety officials in December 2010.

The spirometry tests measured the amount of air participants could forcibly exhale from their lungs. The volume of air expelled in the first second ($FEV_1$) was compared to the total lung volume exhaled (FVC) and expressed as a ratio ($FEV_1$/FVC). This ratio for participants was compared to spirometry standards for "normal" individuals using a mathematical formula that calculated expected results based on the same ethnicity, age, sex, and height of participants. This ratio was expressed as a percentage with a $FEV_1$/FVC ratio of ≤ 70% considered less than optimal for the purposes of this evaluation. Additionally, spirometry tests were done on the same individual at the beginning and end of the work shift when possible; a decrease of $FEV_1$ of greater than 10% preshift vs. postshift was considered evidence of a workplace exposure or personal exposure (smoking) that resulted in lung obstruction. A decrease of $FEV_1$ between 5% and 10% with symptoms of cough, chest tightness, or wheezing during the shift was considered potential evidence of a work-related change in lung function.

# Results and Discussion

## Formaldehyde

Task-based personal air sampling results for formaldehyde during egg preparation and disinfection in rooms 163 and 164 are shown in Table 2. These air sampling results, collected for 101–134 minutes, show that employees' exposures to formaldehyde were above the NIOSH ceiling limit of 0.1 parts per million (ppm). Employees' exposures would also be above the NIOSH recommended exposure limit (REL) of 0.016 ppm, as an 8-hour time-weighted average (TWA), even if employees had no additional formaldehyde exposure during other work activities. Personal exposures, averaged over the sampling period, were not above the American Conference of Governmental Industrial Hygienists (ACGIH) ceiling limit. However, it is possible that exposures could at times exceed the ACGIH ceiling limit for formaldehyde. The Occupational Safety and Health Administration (OSHA) has an action level of 0.5 ppm and a permissible exposure limit (PEL) of 0.75 ppm for formaldehyde. Both of these limits are 8-hour TWAs. OSHA also has a short-term exposure limit of 2 ppm, which is the maximum exposure allowed over a 15-minute duration. Because our samples were substantially greater than 15 minutes duration and substantially less than 8-hours duration, we cannot compare our results directly to the OSHA limits. However, on the basis of these results, if employees had performed these tasks for an entire work shift their exposures to formaldehyde would likely be below the OSHA limits. Area sampling results, averaged over a 4-hour period during treatment and preparation of egg rings, showed a formaldehyde concentration of 0.12 ppm near the formaldehyde tanks in room 163 and a concentration of 0.098 ppm near the drying racks in room 164.

Table 2. Task-based personal air sampling results for formaldehyde during egg preparation and disinfection (May 2010)

| Location/Activity | Sample duration (minutes) | Concentration (ppm) |
|---|---|---|
| Employee 1: Rooms 163 and 164 | 102 | 0.21 |
| Treating and preparing egg rings | 134 | 0.18 |
| Employee 2: Rooms 163 and 164 | 101 | 0.17 |
| Treating and preparing egg rings | 136 | 0.14 |
| NIOSH ceiling limit | | 0.1 |
| ACGIH ceiling limit | | 0.3 |

We observed procedures and work practices during the egg disinfection operation that could potentially increase air contaminant levels and the potential for dermal contact with formaldehyde. Employees had to open the fume hood sash all the way to be able to place the spindles of egg rings into the formaldehyde solution. Opening a lab hood sash beyond the recommended maximum height reduces the face velocity of the hood and thus the ability of the hood to contain formaldehyde gas. We observed that employees had to reach up and over the edge of the formaldehyde tanks to submerge the spindles of the egg rings. Shorter employees had difficulty performing this task because of the height of the formaldehyde tank openings. These employees had to stand on stools to reach the tank opening. Even though employees had gauntlet length outer gloves, we observed that the formaldehyde solution flowed between the employees' outer and inner gloves as they reached into and placed the egg ring spindles into the tanks. We also observed employees manually squeezing the formaldehyde from the rings with gloved hands to speed up the spindle drying process.

ACGIH considers formaldehyde to be a sensitizer from dermal contact or inhalation exposure. To reduce the risk of skin or respiratory tract sensitization, dermatitis, eye or lung irritation, and cancer, engineering controls and stringent work practices should be employed to reduce dermal exposure and keep air contaminant levels as low as possible.

Employees involved in the egg preparation process wore North Safety half-mask air purifying respirators with filter cartridges approved for formaldehyde or combination multicontaminant/P100 respirator cartridges. Employees wore normal length natural rubber latex gloves underneath gauntlet style nitrile gloves, safety glasses, and a lab coat. The wall-mounted emergency eyewash bottle in the egg preparation area was upgraded to a plumbed eyewash station shortly before our May 2010 site visit.

## Inhalable Particulate Matter and Scanning Electron Microscopy

Results of personal air sampling for inhalable particulate matter and scanning electron microscope examination of the area air sample filters for the presence of moth scales and other insect debris are provided in Table 3. Employees' exposures to inhalable particulate matter were below 1 milligram per cubic meter ($mg/m^3$) in many work areas. In contrast, substantially higher exposures occurred during moth pouring, work in the egg production room, and during tray scraping. Airborne particulate concentrations were 10 $mg/m^3$ during tray scraping in Room 192, and ranged from 6.9–8.4 $mg/m^3$ during moth pouring. Employees did these tasks for about 1.5 to 2 hours during the work shift. Exposures would likely be greater if they did these tasks for longer periods. We observed that employees doing tray scraping sometimes leaned over the trays and barrel while scraping and therefore positioned themselves directly in front of the LEV hood opening. This could increase their inhalation exposure and obstruct hood exhaust airflow. We observed that employees sometimes used compressed air to clean dust off work surfaces, equipment, their clothing, and PPE. This practice can aerosolize dust particles into the employee's breathing zone.

Results from scanning electron microscope examination of particles in area air samples identified the presence of insect debris, moth scales, and moth diet ingredients. In most of these area air samples, insect debris was more abundant than moth scales or moth diet ingredients. However, the samples collected in the packaging and shipping room and in the tray scraping room contained mostly moth scales. Only a small amount of moth diet ingredients was found on the samples analyzed by scanning electron microscopy. The analytical laboratory reported finding some insect debris in the two field blanks and a few moth diet ingredient particles in one of the field blanks. Although the lab reported fewer overall particles in the two field blanks compared to the other samples, the presence of these particles indicates possible contamination of the samples during collection. Moth scales and other insect debris can be allergens and NIOSH has previously identified employees with symptoms of occupational allergies from exposure to allergenic particulates during work with insects in research and insect rearing facilities [NIOSH 1983, 1984]. Occupational exposure limits (OELs) do not exist for moth scales or other insect debris. However, identification of these occupational allergens in air samples and the range of employees' exposures across different work areas show which areas had the highest exposures.

Table 3. Time-weighted average personal air sample results for inhalable particulate matter (August 2010) and descriptive summary of scanning electron microscopy observations of collected particulate from area air samples (May 2010)

| Location | Work activities | Sample duration (minutes) | Inhalable particulate concentration (mg/m$^3$) | Scanning electron microscope evaluation of particles related to bollworms from area air samples* |
|---|---|---|---|---|
| North side (clean side) | | | | |
| Room 159 | Working in insect diet weight room (weighing in kitchen for 92 minutes in morning) | 348 | 0.72 | Insect debris, some moth scales, small amount of moth diet ingredients |
| Room 160 | Working in kitchen | 350 | 0.98 | Insect debris, a few moth scales, small amount of moth diet ingredients |
| Room 154 – Hexcel stripping | Handling buckets of pupae | 412 | 0.57 | Area air sample for scanning electron microscopy not collected |
| | At stripping hood | 413 | 0.96 | |
| | At stripping hood | 250 | 0.36 | |
| Room 147 – south cutout | Washing floors, cleaning | 405 | 0.44 | Only insect debris was found |
| | Washing floors, cleaning | 402 | 0.48 | |
| Room 301 – north cutout | Cleaning, then outdoors for 60–90 minutes | 300 | 0.78 | Only insect debris was found |
| South side (dirty side) | | | | |
| Moth collection coolers | Moth pouring | 124 | 8.4 | Sample from cooler B – Insect debris, a few moth scales, small amount of moth diet ingredients† |
| | Moth pouring | 124 | 6.9 | |
| | Dropping | 52 | 2.9 | |
| Rooms 196 and 302 – moth collection | Cleaning coolers and rooms | 65 | 0.47 | Sample from cooler B – Insect debris, a few moth scales, small amount of moth diet ingredient† |
| | | 63 | 0.56 | |
| Egg production | Working in egg production room | 382 | 0.24 | Only insect debris was found |
| | | 397 | 0.50 | |
| | | 329 | 5.2 | |
| Rooms 178 and 179 | Working in moth packaging and shipping rooms | 234 | 0.60 | Mostly moth scales, small amount insect debris |
| Room 181 | Irradiation room activities | 262 | 0.14 | Area air sample for scanning electron microscopy not collected |
| Room 192 | Tray scraping | 84 | 10 | Mostly moth scales, some insect debris |

*Some insect debris was found on both field blanks.

†Note: A bulk sample obtained from work station within a cooler contained mostly moth scales with a small amount of insect debris.

## Carbon Dioxide Measurements

$CO_2$ is a metabolic waste product generated by the newly hatched moth larvae, but is also generated by exhaled breath of workers. Spot check measurements for $CO_2$ in the cut-out room by FOH industrial hygienists' in June 2008 indicated that levels in the north side of the cut out room were 4,109 ppm and were 3,554 ppm in the south side of the cut out room. To help decrease $CO_2$ levels, the agency added two exhaust fans in the exterior walls of the cut out room, which increased the dilution ventilation from one air change per hour to slightly more than two air changes per hour. Follow-up spot checks of $CO_2$ levels by FOH industrial hygienists' in September 2009 indicated that levels had decreased to approximately 2,400 ppm.

Our spot check measurements for $CO_2$ during the May 2010 site visit showed that levels in the cutout room were 1,570 ppm in the south side of the cut out room and 1,600 ppm in the north side of the cut out room. Additional spot check measurements during our August 2010 site visit showed that that $CO_2$ levels were 1,260 ppm in the south side of the cut-out room and 2,250 ppm in the north side of the cut out room. These levels were well below the NIOSH and ACGIH short-term exposure limits of 30,000 ppm; however, periodic monitoring to ensure that $CO_2$ levels are maintained well below exposure limits is prudent.

## Heating, Ventilation, and Air-Conditioning System

Heating, ventilation, and air-conditioning (HVAC) was provided throughout the facility by ceiling-mounted fan-coil units that provided 500 cubic feet per minute of airflow per unit. A maintenance employee told us that the system was designed to provide the majority of the facility with approximately 10% outside air. HVAC units were fitted with 1-inch pleated air filters rated at 89% efficiency. Dark rooms and cutout rooms on the clean side were supplied with 100% outdoor air to control heat, odors, and $CO_2$ generated by developing moth larvae.

The moth collection and egg production rooms on the dirty side of the facility were reportedly maintained under negative pressure to help prevent release of moth scales to the clean side via the adjacent corridor. This corridor was separated from the clean side by an air curtain and two pairs of swinging doors in series. Moth scales exhausted from moth collection and egg production passed through fabric filtration units (bag houses) that were reportedly fitted with 99% efficient filtration fabric. Moth scales and other particulates in the eight bag houses dropped into 55-gallon drums. The drums were typically about 30% full after a week of production. A maintenance person wearing an N95 filtering facepiece respirator and lab coat emptied the drums each week by mixing the contents with a water and soap mixture and disposing down the waste drain.

## Local Exhaust Ventilation Measurements and Observations

### Insect Diet Weight Room

During production of batched moth diet mixtures, employees manually poured diet ingredients from bags into a large garbage container. Personal sampling indicated that exposures to airborne particulates were relatively low; however, we observed that dust was generated when employees poured the insect diet ingredients. The garbage container sat on a scale and was positioned underneath a flanged rectangular LEV hood that was angled over the container (Figure 2). The hood had face dimensions of 22 inches by 17.5 inches and it was attached to a 7.5-inch diameter duct that exhausted into an exterior bag house. The top of the garbage container was 10.5 to 26 inches from the face of the hood. The average face velocity of the hood was 222 feet per minute (fpm). The estimated capture velocity at the top of the garbage container was 16–77 fpm. This was below the ACGIH recommended capture velocity of 100–200 fpm for contaminants released at low velocity into moderately still air [ACGIH 2016].


Figure 2. Scale and LEV hood for insect diet ingredient preparation. Photo by NIOSH.

## Kitchen

Employees poured ingredients onto a mixing auger equipped with a partially enclosed LEV hood. The hood opening was 32 inches by 18 inches and was connected to a 5-inch diameter flexible duct, which exhausted into an exterior bag house. The capture velocity at the face of the hood where employees poured ingredients was 100 fpm, which meets the minimum ACGIH capture velocity recommendations [ACGIH 2016]. Employees' exposures to airborne particulates in the kitchen were low, but we observed airborne dust when batched diet ingredients were poured and mixed with bulk wheat germ and soy flour. Additionally, airborne dust was generated when employees rolled and shook the container-liner bags to empty them after pouring.

### Hexcel Stripping

Employees removed implanted pupae from Hexcel sheets (rigid polymer small honeycomb cell sheets made by Hexcel Corporation) by striking the sheets together in the center of a work booth, or by striking the sheets against the bottom surface of the booth. The Hexcel stripping area included two work booths. Each booth was 57 inches wide and had side and back walls that were 30 inches tall. Each work booth was also fitted with two LEV canopies across the top (Figure 3). The LEV hoods exhausted into a bag house outside the facility. The capture velocity across the front of the booths was 260–280 fpm. Employees' exposures to airborne particulates were low, but we observed airborne dust during this procedure. Additionally, we observed that some employees leaned into the hood while performing this task, which could interfere with airflow in the hood and could potentially increase their airborne dust exposures. Employees wore long-sleeve lab coats, hair coverings, gloves, and N95 filtering facepiece respirators during Hexcel stripping.

Figure 3. An employee standing at the face of the work booth performing the Hexcel stripping operation in the booth. Photo by NIOSH.

## Moth Collection

Employees had relatively high exposures to inhalable particulates during moth pouring, ranging from 6.9–8.4 $mg/m^3$. Employees wore N95 filtering facepiece respirators when working in this area. Airborne dust, primarily from insect debris, appeared to be the highest as moths were poured from metal trays into cylindrical containers. During pouring, employees held a flexible duct as close as possible to capture insect debris (Figure 4). However, we observed that a substantial portion of the airborne insect debris was not captured by the duct and therefore spread into the employees' breathing zone. We also observed that insect debris contaminated employees' clothing. The 2.25-inch diameter flexible duct had a capture velocity (measured 2.25 inches from the center of the duct face) of 230 fpm in coolers A/B in the 1X collection room and 330 fpm in coolers C/D in the 2X collection room. The facility manager said that exhausting larger volumes of air from the coolers for the duration of this process was not feasible because the loss of cold air would cause temperatures in the coolers to rise and cause the adult moths to become too active. Adding a flange to the duct would increase capture velocity, but would not increase overall volumetric exhaust.


Figure 4. An employee pouring moths into a small cylindrical container. Photo by NIOSH.

## Moth Packing and Shipping

Employees' exposures to airborne particulates in this area were very low; however, we observed that airborne particulates were generated during transfer of moths from the cylindrical canisters into metal shipping magazines in the packing room. Employees wore N95 filtering facepiece respirators when emptying moth canisters. An LEV hood measuring 21 inches by 17 inches was angled over the shipping container (Figure 5). The capture velocity 12 inches from the face of the hood, where employees transferred moths, was 130 to 240 fpm.


Figure 5. An employee manually dumping irradiated moths from cylindrical containers into the shipping crate. Photo by NIOSH.

## Tray Scraping

Employees scraped debris from moth trays into a plastic barrel that was placed approximately 12 inches beneath an LEV duct measuring 7 inches in diameter (Figure 6). In addition, a large fan was often used to blow airborne particulates away from the tray scraping barrel; however, use of this fan decreased the already limited effectiveness of this small LEV duct. We observed considerable amounts of airborne particulate when employees were scraping moth trays. Personal air samples collected during tray scraping revealed high particulate concentrations of 10 $mg/m^3$, indicating that the exhaust ventilation was ineffective. Employees wore N95 filtering facepiece respirators in this area. During our evaluation in November 2009, the capture velocity 12 inches from the duct opening was 40–60 fpm, which was below the ACGIH recommendation of 100–200 fpm [ACGIH 2016]. Following that site visit, a rectangular tapered hood with face dimensions of 36 inches by 24 inches was installed. The hood was positioned at an angle from the back of the drum, similar to the hood placement in the insect diet weight room. The top of the plastic barrel was 9 inches to 30 inches from the face of the hood. The capture velocity for the new hood was 40–100 fpm, at 12 inches from the face of the hood, which was still less than recommended.


Figure 6. Tray scraping operation area prior to installation of the LEV hood. Photo by NIOSH.

## Respirator Use Observations

During our site visits we observed some instances of improper respirator use. Employees wearing half-mask respirators for formaldehyde while working in the egg preparation area indicated that they did not regularly inspect the respirators or change their respirator cartridges. They also stated that respirators were stored on a table in the egg ring drying room. We observed that an employee wearing an N95 filtering facepiece respirator wore both straps over the top of earmuff cups. We also observed that some employees had cut off one of the two straps of the filtering facepiece respirator. To ensure proper respirator fit, both straps of the respirator must be used. In addition, the straps must be positioned directly against the head and neck, with one strap over the crown of the head and one strap around the base of the neck.

## Medical Evaluation

We held confidential voluntary medical interviews with 17 of 19 full-time employees during the November 2009 site visit. Employee job titles included moth irradiation, maintenance/environmental control, moth production and collection, Hexcel stripping, cutout room, egg production, egg preparation, kitchen, and egg infestation. Many employees held numerous jobs over the years and rotated to different jobs as needed during the production season. Nine employees were female and eight were male. Length of employment at the facility ranged from 1–41 years with an average of 16 years.

Five employees reported respiratory irritation or wheezing. Of these employees, three stated they had been told by a doctor that they had asthma and were prescribed albuterol inhalers, but no diagnostic testing had been done. All three reported their symptoms began while working at the facility, and improved when away from work or when working in parts of the facility with less exposure to moth scales and insect debris. Seven employees reported skin irritation and rash, primarily on their hands and arms. They believed that the dermatitis was associated with insect exposure in the cutout room and Hexcel stripping, bleach exposure in

Hexcel cleaning, and formaldehyde exposure in egg preparation. A few employees expressed concern that there was confusion about what types of PPE were "advised" and what was "mandatory" in all production areas, especially during the production season among seasonal employees. The employer agreed to post this information in each work area in English and Spanish during our November 2009 closing meeting; we verified this was done during our May 2010 visit.

## Questionnaires

A total of 37 employees completed the medical questionnaire in English, and 11 completed the questionnaire in Spanish. Below we report questionnaire findings by language because we were interested in knowing if there were differences in symptom prevalence or reporting between these groups. The average length of employment for those completing the questionnaire in English was 9.3 years (range: 1 month to 40 years); the average length of employment for those completing the questionnaire in Spanish was 2.4 years (range: one week to 4 years). Participants worked in all areas of the facility, with many reporting routinely working in multiple areas as needed, especially during the summer production season.

Table 4 shows the prevalence of symptoms of irritation and/or allergy reported by participants to occur regularly after their work shift. Symptom reporting was similar between those who completed the questionnaire in English and Spanish.

Table 4. Symptoms reported by participants to occur regularly after their work shift (May 2010)

| | English (N = 37) | Spanish (N = 11) |
|---|---|---|
| Itching or tearing eyes | 9 (24%) | 2 (18%) |
| Stuffy or runny nose | 8 (22%) | 3 (27%) |
| Sneezing | 4 (11%) | 2 (18%) |
| Skin rash or hives | 6 (16%) | 2 (18%) |

Table 5 shows reported prevalence of respiratory symptoms and doctor-diagnosed asthma and allergy by questionnaire language. Examples of types of reported doctor-diagnosed allergies included hay fever and dust, cat, and food allergy. Prevalence of reported respiratory symptoms and doctor-diagnosed conditions of asthma and allergy shown in Table 5 were higher for those completing the questionnaire in English as compared to Spanish. Table 6 shows the self-reported smoking status of participants. Of those participants who completed the questionnaire in English, 16 of 34 (47%) reported being current or ex-smokers. Of the 10 participants who completed the questionnaire in Spanish and reported smoking status, seven never smoked, and three were ex-smokers (30%).

Table 5. Symptoms reported by participants by questionnaire language (May 2010)

| | English (N = 37–40) | Spanish (N = 10–11) |
|---|---|---|
| Wheezing | 7 (19%) | 0 |
| Chest tightness/shortness of breath/difficulty breathing | 3 (8%) | 0 |
| Awake from sleep with cough/chest tightness | 4 (11%) | 0 |
| Recurrent cough | 6 (16%) | 1 (10%) |
| Told by a doctor you have asthma | 5 (14%) | 0 |
| Told by a doctor you have allergies | 10 (27%) | 0 |

Table 6. Smoking status reported by participants by questionnaire language (May 2010)

| | English (N = 34) | Spanish (N = 10) |
|---|---|---|
| Current smoker | 11 (32%) | 0 |
| Never smoked | 21 (62%) | 7 (70%) |
| Ex-smoker | 5 (15%) | 3 (30%) |

In addition to differences in current smoking status, several factors could have contributed to the higher reporting of respiratory symptoms between those who completed the questionnaire in English as compared to Spanish. Employees who completed the questionnaire in English had on average worked at the facility longer (9.3 vs. 2.4 years), so had longer-term exposure to known allergens in the workplace. We could not compare symptom prevalence by job title or location because during the main production season many employees worked throughout the facility as needed. Additionally, there were anecdotal reports from Spanish questionnaire participants of concerns about confidentiality and job security; this could have led to underreporting of symptoms.

## Spirometry

In May 2010, a prespirometry questionnaire was administered by FOH medical personnel to assess whether participants had any medical conditions that prevented their participation, such as current flu or bronchitis, middle ear infection, injury, or elevated blood pressure. One individual was excluded based on their responses. In May 2010, 46 employees participated in FOH administered spirometry. In September 2010, 47 employees participated in FOH administered spirometry. Preshift/postshift results were measured for a total of 57 individuals, with 35 individuals participating in both the May and September testing. A preshift/postshift decrease in $FEV_1$ of greater than 10% was seen in 3/57 (5.3%) participants, which was considered consistent with lung obstruction. Among these three participants, two were current smokers and one was a former smoker; we did not note whether or not they had smoked on their day of testing. These three participants had worked at the facility for 4–8 years in various job titles. One of these three employees reported sneezing and itchy eyes after work as well as cough and wheeze; the other two employees did not answer the questions about health symptoms. An additional 8/57 (14%) participants had preshift/postshift decreases of $FEV_1$ of between 5% and 10%; 6 of these 8 participants reported respiratory symptoms on their symptom questionnaire. This decrease in $FEV_1$ in 6 participants who also reported symptoms of cough, chest tightness, or wheezing during the shift was considered by both FOH and NIOSH as potential evidence of a work-related change in lung function. During the May 2010 spirometry testing, 4/46 (8.7%) participants had a $FEV_1/FVC$ ratio of ≤ 70%, which is less than optimal in this population. This occurred on preshift spirometry for three participants and on postshift spirometry for one participant. Information about $FEV_1/FVC$ ratios for the September 2010 FOH testing are not available.

# Conclusions

Employees at the PBWRF were exposed to multiple allergens and irritants in many areas in the facility. These include formaldehyde, bleach, insects, insect debris, insect diet ingredients, and latex gloves. Air sampling results showed that employees were overexposed to formaldehyde during egg preparation and disinfection according to NIOSH criteria. In addition, employees had dermal exposure and potential for skin sensitization to formaldehyde due to the depth of the dipping tanks and formaldehyde solution getting into their outer gloves when placing egg rings into the tanks. Inhalable particulate matter containing moth scales, insect debris, or insect diet ingredients was not well controlled in the moth pouring, egg production, and tray scraping areas indicating that improvements in LEV were needed. Medical interviews and questionnaire responses showed that employees were experiencing health effects such as eye, respiratory, and skin irritation that were consistent with exposures to irritants and allergens. The spirometry results discussed above along with respiratory symptoms reported by some employees provided evidence of potential work-related changes in lung function; however personal factors such as smoking must also be considered. Once someone develops allergic symptoms these symptoms can continue to occur even at very low exposures and continued exposure may lead to more severe symptoms. Employees with severe allergic symptoms to multiple substances present in the work environment may not be able to work in the production parts of the facility. The self-reported symptoms of allergy and respiratory irritation are consistent with previous NIOSH reports that identified employees with symptoms of occupational allergies during work with insects in research and insect rearing facilities [NIOSH 1983, 1984].

# Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage the appropriate managers and employees to use a labor-management health and safety committee or working group to discuss our recommendations and develop an action plan on the basis of the conditions relevant to the facility today. Those involved in the work can best set priorities and assess the feasibility of our recommendations for the specific situation at the PBWRF.

Our recommendations are based on an approach known as the hierarchy of controls (Appendix A). This approach groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or feasible, administrative measures and PPE may be needed.

## Elimination and Substitution

Eliminating or substituting hazardous processes or materials reduces hazards and protects employees more effectively than other approaches. Prevention through design, considering elimination or substitution when designing or developing a project, reduces the need for additional controls in the future.

1. Continue research on substitutes for formaldehyde in egg disinfection that are less hazardous for employees yet effective as disinfectants.
2. Eliminate the use of latex gloves. Use nitrile gloves for protection against formaldehyde and other dermal hazards.

## Engineering Controls

Engineering controls reduce employees' exposures by removing the hazard from the process or by placing a barrier between the hazard and the employee. Engineering controls protect employees effectively without placing primary responsibility of implementation on the employee.

1. Construct a permanent platform at the formaldehyde disinfection tanks in the egg preparation room. To decrease the potential for dermal exposures, platforms should be adjustable, but tall enough to ensure that employees do not have to reach up and over the formaldehyde tanks.
2. Install a larger lab hood for egg disinfection so that employees do not need to open the hood sash completely to place the spindles into formaldehyde solution.
3. Use hooks or tongs to lower egg spindles into the formaldehyde containers to limit the need to submerge gloved hands and forearms into the formaldehyde solution.
4. Improve the capture velocity of the exhaust hood in the tray scraping area by installing a flanged hood and increasing exhaust flow.
5. Consult with a ventilation engineer to modify and improve the LEV for moth pouring. Exhaust ventilation systems that filter and recirculate air are commercially available and would ensure that the cooled air is not exhausted out of the room.

## Administrative Controls

The term administrative controls refer to employer-dictated work practices and policies to reduce or prevent hazardous exposures. Their effectiveness depends on employer commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that policies and procedures are followed consistently.

1. Instruct employees who disinfect eggs to allow spindles of egg rings to drip dry in the hood rather than manually squeezing the formaldehyde. This change will help reduce the risk of additional dermal and inhalation exposure.

2. Provide and instruct employees to use a vacuum with high efficiency particulate air filters instead of using compressed air to clean work surfaces, equipment, clothing, and PPE.
3. Rely on the hooded LEV to remove airborne particulate during the moth tray scraping operation. Do not use the large floor fan for additional ventilation as this will diminish the effectiveness of the LEV.
4. Include guidance on filter change out, respirator maintenance, and respirator storage in the respiratory protection program.
5. Educate newly hired employees on workplace exposures, potential health effects, and ways to limit exposures such as proper use of equipment, LEV, and PPE. This hazard communication education should be repeated for all employees annually at the beginning of the main production season in conjunction with respiratory protection training.
6. Advise employees who have concerns about health symptoms that may be related to work such as dermatitis or respiratory irritation to seek medical attention from a healthcare provider with experience in occupational medicine. Symptoms should also be reported to facility managers. Employees should continue to be evaluated under the agency's medical surveillance program, and referred for further evaluation as needed based on their spirometry results.

## Personal Protective Equipment

Personal protective equipment is the least effective means for controlling hazardous exposures. Proper use of PPE requires a comprehensive program and a high level of employee involvement and commitment. The right PPE must be chosen for each hazard. Supporting programs such as training, change-out schedules, and medical assessment may be needed. Personal protective equipment should not be the sole method for controlling hazardous exposures. Rather, PPE should be used until effective engineering and administrative controls are in place.

1. Instruct employees who work in the egg preparation area to regularly inspect respirators and change filters following employer guidance. In addition, do not store respirators in the work area. After cleaning, respirators should be stored in closable containers or bags in a clean area.
2. Require the use of respiratory protection to prevent inhalation and mucous membrane contact with airborne allergens in moth collection during moth pouring and during tray scraping if the LEV system cannot adequately control employee exposures to moth scales or other insect debris.
3. Eliminate the use of latex gloves. Provide and require the use of nitrile gloves in all areas where employees are at risk of dermal exposure to potential allergens.
4. Give employees working in the egg disinfection area longer cuffed nitrile gloves to minimize dermal exposure to formaldehyde.
5. Ensure that employees consistently wear required PPE for their work area, and encourage employees to wear advised PPE.

6. Provide employees working in the moth collection rooms with coveralls that are laundered on site because of the amount of airborne dust generated during this operation.

# Appendix A: Occupational Exposure Limits and Health Effects

NIOSH investigators refer to mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a pre-existing medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a TWA exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended STEL or ceiling values. Unless otherwise noted, the STEL is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- The U.S. Department of Labor OSHA PELs (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits. These limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH RELs are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2010]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, PPE, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Another set of OELs commonly used and cited in the United States is the ACGIH TLVs. The TLVs are developed by committee members of this professional organization from a review of the published, peer-reviewed literature. TLVs are not consensus standards. They are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2017].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at http://www.dguv.de/ifa/GESTIS/GESTIS-Internationale-Grenzwerte-für-chemische-Substanzen-limit-values-for-chemical-agents/index-2.jsp, contains international limits for more than 2,000 hazardous substances and is updated periodically.

OSHA requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970 (Public Law 91–596, sec. 5(a)(1))]. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions. NIOSH investigators also encourage use of the hierarchy of controls approach to eliminate or minimize workplace hazards. This includes, in order of preference, the use of (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., LEV, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) PPE (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting employee health. Control banding focuses on how broad categories of risk should be managed. Information on control banding is available at http://www.cdc.gov/niosh/topics/ctrlbanding/. This approach can be applied in situations where OELs have not been established or can be used to supplement existing OELs.

## Formaldehyde

The International Agency for Research on Cancer classifies formaldehyde as a human carcinogen (group 1) on the basis of associations between formaldehyde exposure and nasopharyngeal cancer and leukemia [Baan et al. 2009]. NIOSH considers formaldehyde as a potential occupational carcinogen, and the U.S. Department of Health and Human Services lists formaldehyde as reasonably anticipated to be a human carcinogen in its 14th report on carcinogens [NIOSH 1981; NTP 2016].

The OSHA general industry standard for airborne exposure to formaldehyde [29 CFR 1910.1048] is a PEL of 0.75 ppm for an 8-hour TWA, an action level of 0.5 ppm for an 8-hour TWA, and a short-term exposure limit of 2 ppm for a 15-minute TWA. These limits were established to reduce the risk to workers for cancer; eye, nose, and throat irritation; and sensitization. The OSHA standard requires medical surveillance for employees exposed to formaldehyde at or above the action level or short-term exposure limit.

The NIOSH REL for formaldehyde is 0.016 ppm for up to an 8-hour TWA. NIOSH also has a 15-minute ceiling limit of 0.1 ppm that is not to be exceeded during a work shift [NIOSH 2010]. Following the NIOSH carcinogen policy in existence at the time, NIOSH set the REL to the "lowest feasible concentration," which for formaldehyde was defined as the analytical limit of quantification of 0.016 ppm for up to 8 hours [NIOSH 1981]. Since then, experience has shown that this REL is actually not the "lowest feasible concentration" because formaldehyde in the ambient air can exceed 0.016 ppm, a fact NIOSH has acknowledged [Lemen 1987]. In addition, NIOSH's current carcinogen policy acknowledges that, for most carcinogens, there is no known safe exposure level. A risk management approach based on this premise provides employers with a uniform approach to handling occupational carcinogens. NIOSH will continue to recommend reducing exposures to occupational carcinogens according to the hierarchy of controls through elimination or substitution and implementation of engineering controls, if practical, and the use of administrative controls before use of PPE [NIOSH 2016].

ACGIH® does not have an 8-hour TWA, but has a ceiling limit of 0.3 ppm [ACGIH 2017]. An ACGIH ceiling limit is an exposure that should not be exceeded at any time during the work shift. The ceiling limit is intended to minimize the potential for eye and upper respiratory tract irritation. Additionally, ACGIH considers formaldehyde to be a sensitizer and a suspected human carcinogen [ACGIH 2001].

# Appendix B: Detailed Process Description of PBWRF Work Areas

## Production Areas

### Egg Preparation

Paper rings that had been implanted with insect eggs were collected from the egg implantation room, stacked onto spindles, rinsed with a soap and water solution, then rinsed with water and allowed to drip dry in small rigid plastic holding tanks (Figure B1).

Figure B1. Spindle of egg rings in plastic holding tanks after being washed with soap and water. Photo by NIOSH.

After the initial washing and drying, employees manually immersed the egg ring spindles into tanks of dilute (9%) formaldehyde solution for 30 minutes (Figure B2). The employer had previously tried dilute sodium hypochlorite and chlorhexidine to disinfect eggs, but formaldehyde provided the best disinfection results. The formaldehyde solution tanks were located in a laboratory fume hood and were covered during soaking and when not in use. The formaldehyde solution in the tanks was reportedly changed every 6 weeks. After soaking in formaldehyde, employees removed the egg ring spindles and let the spindles drip dry above the formaldehyde tanks for 10 minutes. After drying, the egg rings were rinsed with water and cleaned again in a soap and water solution. Employees then placed the egg rings on drying racks in the drying area.


Figure B2. An employee preparing to submerge a spindle of egg rings into the formaldehyde tank located in a lab fume hood. Photo by NIOSH.

## Egg Infestation

After disinfection and drying, the egg rings from the insect egg preparation process were cut into quarters. Each ring quarter contained 4,500 to 6,000 eggs. The egg ring quarters were placed within covered plastic individual larva rearing units that contained a food source for hatching larva. This process was referred to as infestation.

## Darkroom

The larva rearing units from the egg infestation stage were placed on maturation carts and transferred to a darkroom where they remained for 8 days. The carts were arranged in rows so that newly arrived carts were in a single horizontal row at one end of the room, they were advanced by one row each day over the next 8 days so that carts of mature larva ended up nearest the cutout rooms at the end of the 8-day maturation period. This room had a dedicated air handling unit that maintained positive pressure in the room relative to the surrounding areas. Because newly hatched moth larvae generated considerable metabolic heat along with $CO_2$ and odors, the darkrooms were supplied with 100% outdoor air. Employees entered the darkroom daily to advance the maturation carts forward one row toward the cutout room and to clean the floors.

## Cutout

After the 8-day maturation period in a darkroom, the maturation carts were transferred to a cutout room where they remained for 7 additional days while larvae fed on the insect diet in the rearing units and continued to mature (Figure B3). Larvae ate their way out of the rearing units and dropped onto rectangular Hexcel sheets, positioned beneath the suspended rearing units, where they implanted and pupated (Figure B4). The Hexcel sheets were cleaned and reused until showing visible signs of wear and tear. Sheets of cardboard were placed under each Hexcel sheet and were also reused after being cleaned. Hexcel sheets were changed out by employees 10–12 times over a 7-day period, with six to eight of these changeouts required during the 24–48 hours of most rapid growth. During the production season, employees spent 4–6 hours daily in the cutout rooms. Employees wore N95 filtering facepiece particulate respirators. Cutout rooms were also supplied with 100% outdoor air because of $CO_2$ generated by the larva.


Figure B3. Maturation carts with larvae rearing units in cutout room. Photo by NIOSH.

Figure B4. Hexcel sheet where larvae implant and pupate after leaving the rearing unit. Photo by NIOSH.

Some larvae that emerge from the rearing units fail to implant in the Hexcel sheets and instead fall to the cutout room floor. Employees use a household leaf blower to blow insect larvae bodies and other insect debris to one corner for collection with a high efficiency particulate air vacuum.

## Hexcel Stripping

The Hexcel sheets were removed from a cutout room when they were approximately 60% implanted with pupae. Employees' collected pupae from the Hexcel sheets by striking the sheets together or against the bottom of the ventilated work booth. The LEV hood exhausted into a bag house. Employees wore safety glasses, latex gloves, surgical masks, and lab coats. Pupae dropped into a bucket beneath the hood and were weighed and examined. The pupae were then placed onto trays and transported to a prep area where they were prepared to either go to egg production rooms or moth collection rooms.

## Egg Production

Approximately 3% of pupae were hatched into moths in the egg production rooms to provide an adequate numbers of eggs to maintain the moth colony from year to year. Egg production rooms were maintained at 80 degrees Fahrenheit and 80% relative humidity. After eggs were implanted on the specialized egg rings by the moths, they were transferred to the egg preparation area for disinfection, as previously discussed. Moth scales and debris were exhausted through polyvinyl chloride pipes to scale collectors on the building's exterior.

## Moth Production and Collection

Another set of rooms was used to hatch pupae for moths destined for irradiation and eventual release. Once adult moths emerged from pupae inside cabinets in the moth collection rooms, they were transported pneumatically through a sealed system to four large walk-in coolers located within these rooms. The colder temperature in the coolers kept the moths in a semidormant state to prevent flying and wing damage. In a process called dropping, chilled moths were dropped from the sealed transport system into pans and then manually transferred into trays for weighing. After the moth trays were weighed, the moths were poured into small cylindrical canisters for irradiation and sterilization. Employees manually held a flexible duct LEV adjacent to the cylindrical canister during moth pouring to collect airborne particulate. Employees were required to wear N95 filtering facepiece respirators, lab coats, and hairnets in the moth collection rooms.

## Moth Irradiation

An employee irradiated small cylindrical canisters of moths that arrived from the moth collection area. Irradiated (sterilized) moths were then transferred to the refrigerated packing room via a pass-through cooler.

## Moth Packaging and Shipping

An employee received the small cylindrical canisters of irradiated adult moths through the pass-through from the cooler that adjoined the irradiation room and the refrigerated packing room. In the packing room, the employee poured moths from the canisters into a metal shipping magazine beneath an LEV hood. Coolant tubes were then inserted into the shipping magazine, and the magazine was placed in a shipping box. Each magazine contained approximately 2.6 million moths. The boxed magazines were transported by pickup truck and air freight to small aircraft that released the moths above cotton fields on the basis of ongoing surveillance for naturally occurring bollworm pests.

# Insect Production Support Areas

## Diet Weight Room

One employee weighed and hand mixed powdered ingredients in a 32-gallon garbage container that sat beneath an LEV hood. Approximately 24 hours per week were spent mixing insect diet ingredients during the production season. The diet was a complex mixture of approximately 24 dry and liquid ingredients and included calco red dye. This dye allows the irradiated moths that were released to be distinguished from naturally occurring moths in cotton fields for surveillance activities.

## Kitchen

An operator put the batched insect diet mixture from the diet weight room into an auger along with bulk soy flour and wheat germ. These bulk ingredients came in bags that were manually slit and emptied into the LEV-equipped auger. The diet was mixed and cooked in the extruder. The diet was cooled and transported by conveyor to the implant room where it was put into plastic rearing units with sections of implanted egg rings.

## Hexcel Cleaning

Hexcel sheets used during larva pupation were cleaned and reused. Sodium hypochlorite (bleach) (12.5%) was pumped into wash tubs and diluted with water. Hexcel sheets soaked for 30 minutes to remove insect debris and then dried. Approximately 2,600 sheets of Hexcel and cardboard were used each day during the production season. Hexcel sheets could be reused for several years before replacement was required.

## Cardboard Cleaning

Cardboard sheets were passed through an automated cardboard cleaner that brushed off insect debris. Managers reported that the cardboard sheets were reused an average of four times before replacement.

## Tray Scraping

Moth trays were cleaned and prepared for reuse in the tray scraping room. An employee scraped debris from moth trays into a barrel beneath an LEV hood. Employees were required to wear coveralls, hairnet, safety glasses, N95 filtering facepiece respirator, and rubber boots during this process. Glove use was advised but not mandatory.

# Appendix C: Tables

Table C1. Personal protective equipment requirements, established by the PBWRF

| Work Area/Duty | N95 filtering facepiece | Elastomeric half mask respirator | Gloves | Hairnet | Gown | Lab coat | Hearing protection | Safety glasses | Apron/ boots | Irradiation badge |
|---|---|---|---|---|---|---|---|---|---|---|
| Outside clean-up Bleach tanks | | | A | | | | | M | A | |
| Cutout 1x and 2x | | | | | | | M | | | |
| Stripping | M | | A | | | | A | M | | |
| Cutout leaf blower | M | | | | | | M | M | | |
| Cardboard Cleaner | M | | A | | | | M | M | | |
| Cardboard Stacking | M | | A | | | | | | | |
| Hexcel high pressure rinsing | | | A | | | | M | | | |
| Dark room 1x and 2x | | | | | | | M | | | |
| Infest production line | | | M | M | M | | M | | | |
| Infest air hose* | | | | | | | M | M | | |
| Infest outside Clean-up | | | M | | | | | | A | |
| Egg prep† | | M | M | M | M | | | M | | |

A = Advised

M = Mandatory

*All personnel present must wear safety glasses and ear protection while air hose is in use.

†Elastomeric half-mask respirators and safety glasses are mandatory during placement and extraction of egg rings from the formaldehyde tanks and rinse tanks. They are no longer mandatory during the process of laying egg rings on dry racks, but are advised.

Table C1 Continued. Personal protective equipment requirements, established by the PBWRF

| Work Area/Duty | N95 filtering facepiece | Elastomeric half mask respirator | Gloves | Hairnet | Gown | Lab coat | Hearing protection | Safety glasses | Apron/ boots | Irradiation badge |
|---|---|---|---|---|---|---|---|---|---|---|
| QC lab-moth handling and clean-up | M | | | | | | | | | |
| Kitchen clean-up | | M | | | | | | | A | |
| Kitchen extruder | | | | | | | M | | | |
| Cleaning chemicals | | | M | | | | | A | | |
| Layers 1x | M | | M | A | | A | M | A | | |
| Layers 2x | M | | M | A | | A | A | A | | |
| Moth collection drops | M | | A | M | | M | | A | | |
| Moth collection vacuum lines | M | | | | | | M | | | |
| Moth collection Box/tray cleaning | M | | A | M | | M | | M | | |
| Irradiation | | | | | | | | | | M |
| Shipping/Packaging | M | | A | A | | M | | | | |

# References


ACGIH [2001]. Documentation of the threshold limit values and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ACGIH [2016]. Industrial ventilation: a manual of recommended practice for design, 29th edition. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ACGIH [2017]. 2017 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

Baan R, Grosse Y, Straif K, Secretan B, El Ghissassi F, Bouvard V, Benbrahim-Tallaa L, Guha N, Freeman C, Galichet L, Cogliano V, on the behalf of the WHO International Agency for Research on Cancer Monograph Working Group [2009]. A review of human carcinogens-Part F: chemical agents and related occupations. Lancet Oncol *10*(12):1143–1144.

Centers for Disease Control and Prevention [1984]. Work-related allergies in insect-rearing facilities. MMWR *33*(31):448;453–454.

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

Lemen RA [1987]. Official letter from RA Lemen, Director, Division of Standards Development and Technology Transfer, National Institute for Occupational Safety and Health, U.S. Department of Health and Human Services, Cincinnati, OH, to Tom Hall, Docket Office, Department of Labor, Washington, DC, February 9.

NIOSH [1981]. Current intelligence bulletin 34 – formaldehyde: evidence of carcinogenicity. Cincinnati, OH: U.S. Department of Health and Human Services, Center for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 81-111 (1981, updated 1997).

NIOSH [1983]. Metabolism and radiation research laboratory (MRRL). By Bauer M, Patnode R, Morring K. Morgantown, WV: U.S. Department of Health and Human Services, Center for Disease Control, National Institute for Occupational Safety and Health, NIOSH Health Hazard Evaluation Report 82-002-1312, https://www.cdc.gov/niosh/hhe/reports/pdfs/82-2-1312.pdf.

NIOSH [1984]. Insect rearing facilities, Agricultural Research Service, U.S. Department of Agriculture. By Bauer M, Patnode R. Morgantown, WV: U.S. Department of Health and Human Services, Center for Disease Control, National Institute for Occupational Safety and Health, NIOSH Health Hazard Evaluation Report 81-121-1421, https://www.cdc.gov/niosh/hhe/reports/pdfs/81-121-1421.pdf.

NIOSH [2010]. NIOSH pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2010-168c, http://www.cdc.gov/niosh/npg/.

NIOSH [2016]. Current intelligence bulletin 68: NIOSH chemical carcinogen policy. By Whittaker C, Rice F, McKernan L, Dankovic D, Lentz TJ, MacMahon K, Kuempel E, Zum-walde R, Schulte P, on behalf of the NIOSH Carcinogen and RELs Policy Update Committee. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2017-100.

NIOSH [2017]. NIOSH manual of analytical methods (NMAM). 5th ed. O'Connor PF, Ashley K, eds. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2014-151, http://www.cdc.gov/niosh/nmam.

NTP [2016]. Report on carcinogens, 14th ed. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Toxicology Program, https://ntp.niehs.nih.gov/pubhealth/roc/index-1.html.

Qaseem A1, Wilt TJ, Weinberger SE, Hanania NA, Criner G, van der Molen T, Marciniuk DD, Denberg T, Schünemann H, Wedzicha W, MacDonald R, Shekelle P [2011]. Diagnosis and management of stable chronic obstructive pulmonary disease: a clinical practice guidelines update from the American College of Physicians, American college of Chest Physicians, American Thoracic Society, and the European Respiratory Society. Ann Intern Med *155*(3):179–191, https://doi.org/10.7326/0003-4819-155-3-201108020-00008.

Redd JT, Voorhees RE, Törok TJ [2007]. Outbreak of lepidopterism at a Boy Scout camp. J Am Acad Dermatol *56*(6):952–955, http://dx.doi.org/10.1016/j.jaad.2006.06.002.

Suarthana E, Shen A, Henneberger PK, Kreiss K, Leppla NC, Bueller D, Lewis DM, Bledsoe TA, Janotka E, Petsonk EL [2012]. Post-hire asthma among insect-rearing workers. J Occup Environ Med *54*(3):310–317, http://dx.doi.org/10.1097/JOM.0b013e31823fe098.

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The Health Hazard Evaluation Program investigates possible health hazards in the workplace under the authority of the Occupational Safety and Health Act of 1970 (29 U.S.C. § 669(a)(6)). The Health Hazard Evaluation Program also provides, upon request, technical assistance to federal, state, and local agencies to investigate occupational health hazards and to prevent occupational disease or injury. Regulations guiding the Program can be found in Title 42, Code of Federal Regulations, Part 85; Requests for Health Hazard Evaluations (42 CFR Part 85).

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## Availability of Report

Copies of this report have been sent to the employer and employees at the facility. The state and local health department and the Occupational Safety and Health Administration Regional Office have also received a copy. This report is not copyrighted and may be freely reproduced.

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