HealthHazard Evaluation Program

Evaluation of Potential Hazards During Harvesting and Trimming Cannabis at an Indoor Cultivation Facility

HHE Report No. 2019-0152-3381

February 2022

Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

Authors: Michael P. Grant, ScD, CIH

Douglas M. Wiegand, PhD

Brett J. Green, PhD

Angela R. Lemons, MS

Analytical Support: Bureau Veritas North America, Inc.

Desktop Publisher: Shawna Watts

Editor: Cheryl Hamilton

Industrial Hygiene Field Assistance: Jessica Ramsey, Bradley King, Josie Ehlers

Logistics: Donald Booher, Kevin Moore

Keywords: North American Industry Classification System (NAICS) 111419 (Other Food Crops Grown Under Cover), Colorado, Cannabis, Cultivation, Agriculture, Fungus, Endotoxin, Psychosocial, Delta-9 Tetrahydrocannabinol, Delta-9 Tetrahydrocannabinol Acid, Cannabidiol, Cannabinol, THC, THCA, Cannabinoids, CBD, CBN, Noise, Particles, Musculoskeletal, Ergonomics

Disclaimer

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 USC 669a(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].

Availability of Report

Recommended Citation

NIOSH [2022]. Evaluation of potential hazards during harvesting and trimming cannabis at an indoor cultivation facility. By Grant MP, Wiegand DM, Green BJ, Lemons AR. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2019-0152-3381, https://www.cdc.gov/niosh/hhe/reports/pdfs/2019-0152-3381.pdf.

Table of Contents

Main Report

Supporting Technical Information

This page left intentionally blank

Introduction

Request

Management at an indoor cultivation facility requested a health hazard evaluation of potential hazards during harvesting and trimming of cannabis crops.

Workplace

The facility was a single, large building with two floors. Immediately inside the entrance was a two-floor lobby with space for visitors and employees to wait or take breaks. Offices and a conference room were on the second floor of the lobby area. The cultivation space of the facility was separated into two sides that cultivated and harvested cannabis separately for each of two brand names owned by the same parent company. The facility had a basement, but we were informed that the company did not use that space.

To learn more about the workplace, go to Section A in the Supporting Technical Information

Our Approach

The evaluation was broad in scope, designed to characterize potential hazards among employees harvesting and trimming cannabis plants. Job titles for these employees included grow technicians, cultivation managers, facility managers, and trimming employees. We visited the facility in July and September 2019 and completed the following activities:

- Observed work processes, work practices, and conditions.
- Measured employee exposures to endotoxins in air.
- Sampled surfaces for cannabinoids including delta-9 tetrahydrocannabinol (Δ9-THC), delta-9 tetrahydrocannabinol acid (Δ9-THCA), cannabidiol (CBD), and cannabinol (CBN).
- Measured area exposures to fungi in air.
- Measured particulates in air during trimming and harvesting activities.
- Measured sound levels throughout the cultivation and trimming areas of the facility.
- Completed confidential medical interviews with employees who did cultivation, harvesting, and trimming activities.

To learn more about our methods, go to Section B in the Supporting Technical Information

Our Key Findings

Employees were exposed to endotoxins in the air

- Employees were exposed to endotoxins in the air that were greater than the Dutch Expert Committee on Occupational Safety occupational exposure limit.
- Endotoxins were detected in the air during harvesting and repotting activities where soil and plant matter was disturbed.

Employees were concerned about their potential exposures at work

- Cultivation and harvesting employees reported health and safety concerns about noise, lights that were too bright, and pesticide exposure.
- Trimming employees reported health and safety concerns about indoor environmental quality, use of alcohol to clean workstations, pesticide exposure, ozone exposure, and communication issues.
- Employees from both groups reported allergic, irritant, and musculoskeletal symptoms they believed were associated with their work.

Trimming employees had exposures to highly repetitive work that increased their risk of musculoskeletal disorders

- Trimming employees had exposures to highly repetitive and forceful work, most notably during hand trimming activities.
- Trimming employees spend long periods of time sitting at tables performing manual tasks.

To learn more about our results, go to Section B in the Supporting Technical Information

Our Recommendations

The Occupational Safety and Health Act requires employers to provide a safe workplace.

Benefits of Improving Workplace Health and Safety:

- ↑ Improved employee health and well-being
- ↑ Better workplace morale
- ↑ Easier employee recruiting and retention
- ↑ Enhanced image and reputation
- ↑ Superior products, processes, and services
- ↑ May increase overall cost savings

The recommendations below are based on the findings of our evaluation. For each recommendation, we list a series of actions you can take to address the issue at your workplace. The actions at the beginning of each list are preferable to the ones listed later. The list order is based on a well-accepted approach called the "hierarchy of controls." The hierarchy of controls 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 practical, administrative measures and personal protective equipment (PPE) might be needed. Read more about the hierarchy of controls at https://www.cdc.gov/niosh/topics/hierarchy/.

We encourage the company to use a health and safety committee to discuss our recommendations and develop an action plan. Both employee representatives and management representatives should be included on the committee. Helpful guidance can be found in *Recommended Practices for Safety and Health Programs* at https://www.osha.gov/shpguidelines/index.html.

Recommendation 1: Reduce exposures to endotoxins in the workplace

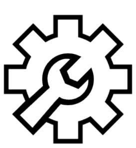
Why? Endotoxins are toxic substances located inside the cell walls of some types of bacteria and are found throughout agricultural environments. Employees can be exposed to endotoxins when soil and plant matter are disturbed. Studies have shown that individuals can have acute and chronic respiratory health effects when exposed to high concentrations of endotoxin.

We found four employees on each side of the facility were exposed to endotoxins in the air greater than the Dutch Expert Committee on Occupational Safety occupational exposure limit. The main soil and plant-disturbing activities that employees did during sampling were harvesting and repotting.

How? At your workplace, we recommend these specific actions:

Use wet methods or high efficiency particulate air (HEPA) filter vacuums instead of dry sweeping.

- Train employees in the proper methods to use while cleaning. Wet methods (e.g., mops or surface wipes) and HEPA-filtered vacuums are preferred when cleaning up soil and debris left on the floor after harvests or repotting activities.



Use tools to move and mix soil when repotting plants.

- Hand tools will reduce the amount of bending and direct contact with soil by employees when repotting. Less direct contact and less bending could reduce potential endotoxin exposure.
- Slowing the pace of work will also help reduce the amount of soil disturbance when repotting plants.

Encourage employees to report any symptoms they believe are work-related to their supervisor.

- Supervisors should refer employees to an occupational health physician or their primary care provider to discuss their individual health concerns and questions about work-related symptoms.

Recommendation 2: Reduce dermal exposures to cannabinoids in the workplace

Why? Occupational exposures to cannabinoids are thought to be mostly through skin absorption and ingestion. The long-term health effects of these occupational exposure routes are currently unknown. We expect to see cannabinoids in production areas but not in nonproduction areas. In this type of facility, cannabinoids found in nonproduction areas are likely brought out of the production areas on gloves and hands. It is important to practice good hand hygiene and cleaning practices in nonproduction areas to prevent unnecessary exposures.

We detected cannabinoids on production and nonproduction surfaces. Employees could be exposed through dermal contact or hand to mouth actions (e.g., eating or drinking).

How? At your workplace, we recommend these specific actions:

Train employees about the importance of removing gloves and washing hands before using the bathroom, eating, drinking, or smoking.

- Instruct employees on proper handwashing techniques and when to wash their hands (e.g., before going on break, at the end of the workday, before using the restroom).
- Ensure access to soap, clean running water, and paper towels or hand dryers in all break areas.
- Require that employees always remove gloves before leaving production areas.
- Incorporate this training into new employee and annual refresher training.

Clean break area surfaces once per shift to reduce potential exposures to cannabinoids.

- Choose an employee or employees to use wet cleaning methods (e.g., 70% alcohol surface wipes) to wipe down high-contact surfaces (e.g., microwave face, refrigerator handles) at least once per shift.
- Incorporate this practice into standard operating procedures and into new employee and annual refresher training.

Encourage cultivation and harvesting employees to wear long sleeves when working.

- Train employees about the importance of protecting themselves from exposures to cannabinoids when touching plants.
- Supply long sleeve scrub options for employees. Other technologies may also be appropriate (e.g., athletic arm sleeves). Ensure that employees understand that all shirts, scrubs, or other sleeve technologies worn during cultivation and harvesting tasks should be laundered regularly.

Recommendation 3: Reduce potential exposures to ozone, light, and noise in the workplace

Why? Low concentrations of ozone may produce a sharp, irritating odor even during brief exposures. Symptoms of ozone exposure include eye irritation, nose and throat dryness, and cough. At higher ozone concentrations, more severe symptoms may develop including headache, pain or tightness in the chest, and shortness of breath or tiredness. Exposures from grow lights in cultivation facilities have not been widely studied. There is a potential for exposure to ultraviolet (UV) light from many types of lightbulbs used in these types of facilities. Overexposures to UV light can cause a number of health effects including skin cancer and eye damage. Noise-induced hearing loss is an irreversible condition that progresses with noise exposure. Unlike some other types of hearing disorders, noise-induced hearing loss cannot be treated medically. Noise-exposed workers can develop substantial noise-induced hearing loss before it is clearly recognized.

We learned that employees had health and safety concerns about exposures to ozone, bright lights, and noise. Ozone generators were attached to analog timers which would be affected by power outages. The ozone generators were intended to be run overnight when no employees were in the building. Employees told us that past power outages led to ozone generation during working hours. Cultivation and harvesting employees worked under grow lights almost continuously throughout their shifts. Loud music was played in production areas and many employees were observed wearing earbud headphones while working in these areas.

How? At your workplace, we recommend these specific actions:

Adjust the current ozone generation practices to reduce the chance of accidental ozone generation with employees present.

- Use ozone generators that have a built-in timer. Leaving the current generator set to be continuously "on" and controlling the electricity with the analog timer is not how the generator was designed to be operated.

- Unplug the ozone generators at the start of each day—if keeping the current setup using analog timers—to prevent the accidental generation of ozone during the shift. Plug the generators in at the end of the shift and ensure the analog timer settings are correct.

Supply employees with the right protective eyewear for the specific wavelengths emitted by the bulbs in the facility.

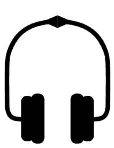
- Train employees about the importance of protecting themselves from exposures to UV light and why wavelength-specific protection is needed.

Encourage cultivation and harvesting employees to wear long sleeves when working.

- Train employees about the importance of protecting themselves from exposures to UV light.
- Provide long sleeve scrub options for employees. Other technologies may also be appropriate (e.g., UV-protective athletic arm sleeves). Ensure that employees understand that all shirts, scrubs, or other sleeve technologies worn during cultivation and harvesting tasks should be laundered regularly.

Reduce noise exposures in production areas.

- Monitor the volume of the music being played in production areas. Playing music (on a speaker or in headphones) adds to the employees' cumulative noise exposure'. No longer playing music in production areas or reducing the volume at which it is played may help address potential overexposures from headphones being used in the workplace.
- Suggest employees keep their headphone volumes at a lower level, which will be easier to do if there is no competing noise from the shared speakers.



Offer hearing protection to employees who wish to use it.

- Train employees upon hiring and at least annually about the hazards of noise exposure.
- Give training about the proper use for the type of hearing protection provided (e.g., earplugs, earmuffs).
- Ensure adequate supplies of hearing protection are available for employees to use.

Recommendation 4: Reduce risks for musculoskeletal disorders

Why? Musculoskeletal disorders are conditions that involve the nerves, tendons, muscles, and supporting structures of the body. They can be characterized by chronic pain and limited mobility. A substantial body of data shows strong evidence of an association between musculoskeletal disorders and certain work-related factors (physical, work organizational, and psychosocial). The preferred method for preventing and controlling work-related musculoskeletal disorders is to design tasks, workstations, and tools and other equipment to match the physiological, anatomical, and psychological characteristics and capabilities of the employee.

Our observations indicate that employees had exposures to highly repetitive and forceful work, most notably during hand trimming and harvesting activities. These exposures increase the risk of musculoskeletal disorders. Trimming employees spent long periods sitting at tables performing their manual tasks. Improving workstations will reduce lower back, shoulder, and neck strain for these employees. Harvesting employees also experienced repetitive work with frequent bending and reaching to access plastic trellis netting and stems on the lower parts of the plants.

How? At your workplace, we recommend these specific actions:

Rotate job tasks for employees performing highly repetitive work.

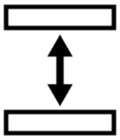
- Develop a job rotation plan to move employees working in high hand and finger motion frequency tasks to other jobs that require using different muscle-tendon groups. An effective job rotation plan will reduce the risk of musculoskeletal disorders.
- Provide frequent breaks for employees working in high hand and finger motion frequency tasks such as hand trimming.

Provide employees with clean, sharp tools.

- Discuss equipment needs with harvesting and trimming employees regularly and replace or maintain tools as needed.
- Develop a cleaning schedule to remove cannabinoids from work and tool surfaces.
- Train employees to clean, lubricate, sharpen, and maintain their tools according to manufacturer recommendations.

Improve the workstations for trimming employees.

- Supply adjustable and comfortable seating for trimming employees.
- Add padded elbow rests to the edges of the trimming tables or otherwise ensure that there are no hard, sharp edges on the trimming tables.
- Include several standing workstations with anti-fatigue mats to allow employees variation and choice of posture during trimming tasks.



Raise all cultivation beds and other ground-level work areas to reduce bending and awkward postures during cultivation and harvesting activities.

- Raising all cultivation beds off the ground allows employees to access the lower parts of the plants and plastic trellis netting with less bending and reaching. This will help employees avoid unnecessary bending when setting up the plastic trellis netting, de-leafing and caring for the plants, and harvesting.
- Raising the children's pool of soil further off the ground when repotting plants and adding an elevated work surface (e.g., washable folding table) to the cleaning area will help employees avoid unnecessary bending during these tasks.

Provide employees with longer-handled brushes for cleaning pots.

- Longer handles will reduce the amount of reaching and bending required during cleaning tasks. Longer handles will also reduce the chance that cleaning produce gets splashed on employees.

Recommendation 5: Obtain regular input from employees about workplace safety and health issues and use this input to improve conditions

Why? Monitoring employee concerns, satisfaction, and well-being is useful for finding areas of focus for intervention and improvement. Engaging employees and asking for their input about work builds trust and morale when they feel their input is valued and useful for improving working conditions.

We learned that employees had safety and health concerns related to the physical working environment (lighting, noise, potential exposures), work organization (e.g., practices and policies), and psychosocial environment (e.g., communication). Exploring these concerns in greater detail may lead to organizational change and improvement based on employee input. Employee safety and health concerns may change over time, so frequent communication is important, especially during times when new or different practices and procedures are implemented.

How? At your workplace, we recommend these specific actions:

Use employee input to guide efforts in improving worker safety, health, and well-being.

- Develop or use existing tools (survey, interview, or focus group questions/topics) to obtain employee input about workplace safety and health and use the results to inform the development or revision of interventions, policies, and practices in the workplace to improve employee safety and health.
- An example tool is the National Institute for Occupational Safety and Health (NIOSH) Well-Being Questionnaire or WellBQ. WellBQ is a survey tool developed to assess

employee well-being across multiple areas, including work evaluation and experience, workplace policies and culture, workplace physical environment and safety culture, health status, and home, family, and society. The WellBQ and instructions are available at www.cdc.gov/niosh/twh/wellbq.

- Use the interview results from this health hazard evaluation (Tables C6 through C8) as a baseline to guide and monitor improvement efforts in areas of concern to employees.

Recommendation 6: Address other health and safety issues we identified during our evaluation

Why? A workplace can have multiple health hazards that cause employee illness or injury. Similar to the ones identified above, these hazards can potentially cause serious health symptoms, lower morale and quality of life for your employees, and possibly increase costs to your business. We saw the following potential issues at your workplace:

- No respiratory protection program was provided for pesticide applicators, although pesticide applicators were certified to apply pesticides by the state Department of Agriculture.
- Incorrect respirator cartridges were being used for the chemical exposures during pesticide application.
- The trimming machine safety switch was taped so that it could be operated with the cover in an open position.
- No eye wash stations were located near the pesticide/nutrient preparation areas.
- Goggles or face shields were not available for employees working with the hydrogen peroxide to wash pots from harvested plants.
- High-percentage alcohol was being sprayed directly onto surfaces in the trimming areas causing many employees to report discomfort from strong odors when performing those tasks.
- Powder-free latex gloves were available in some parts of the facility, latex is a potential allergen source.

Although they were not the focus of our evaluation, these hazards could cause harm to your employees' health and safety and should be addressed.

How? At your workplace, we recommend these specific actions:

Develop a respiratory protection program.

- Contact your local Occupational Safety and Health Administration (OSHA) consultation program for free help in developing your respiratory protection program, addressing questions about PPE, and other safety concerns. Additional information can be found at https://www.osha.gov/html/RAmap.html.

- Ensure that the respiratory protection program also complies with the Environmental Protection Agency (EPA) Agricultural Worker Protection Standard.

Use the correct respirator cartridges for the chemical exposures during pesticide application.

- We learned that pink P100 cartridges were used for pesticide and nutrient application. P100 cartridges are designed to protect against exposures to particulates or fibers, not chemical vapors. Organic vapor (OV) or combination OV and P100 cartridges would be appropriate for the pesticide and nutrient application.

- Consider using the NIOSH MultiVapor™ tool or the OSHA Respiratory Protection eTool to assist with cartridge selection.

Operate the trimming machine according to manufacturer's instructions.

- Do not tape down the safety switch. Operate the machine with the cover in a closed position to prevent getting fingers or clothing caught in moving machinery.

- Use a tool to move the cannabis around inside the machine when the cover is open.

Install plumbed eye wash stations and emergency showers in each of the pesticide/nutrient preparation areas.

- Ensure that eye wash stations and emergency showers are accessible, provide adequate flow of tepid water, and not blocked by equipment.

- Provide training to employees so that they know the locations and how to operate the eye wash and emergency shower and report incidents where the eye wash or shower needed to be used.

- Incorporate this procedure into new employee and annual refresher training.

Provide goggles (not safety glasses) or face shields to employees who wash pots after harvesting.

- Goggles and face shields should be compliant with the American National Standards Institute Standard Z87.1-2015, "American National Standard for Occupational and Educational Personal Eye and Face Protection Devices."

- Face shields should be at least ¾-length or full-length. Smaller-sized shields are not acceptable.

Adjust the cleaning procedures and training for the trimming areas.

- Purchase cleaning wipes to avoid spraying cleaning products.
- If the current practice of spraying cleaning products is kept, reduce the alcohol concentration to 70% alcohol for cleaning hard, nonporous surfaces.
    - Train employees to spray the alcohol directly onto paper towels and then use those paper towels to wipe down surfaces.
    - Provide to training about proper handling of flammable liquids to employees using high-percentage alcohol for cleaning. Training should cover potential fire hazards and instruction about safe handling and storage of flammable liquids.
- Incorporate this procedure and training into new employee and annual refresher training.

Remove powder-free latex gloves from the facility.

- Continue to provide non-latex gloves for employees. Consider using the OSHA guidance publication on PPE: Personal Protective Equipment.

This page left intentionally blank

Supporting Technical Information

Evaluation of Potential Hazards During Harvesting and Trimming Cannabis at an Indoor Cultivation Facility

HHE Report No. 2019-0152-3381

February 2022

Section A: Workplace Information

Background

According to the [National Conference of State Legislatures](), 37 states and 4 territories allow for medical or non-medical adult use of cannabis products as of February 2, 2022. These legal changes have given rise to a rapidly growing industry. As of January 2021, the cannabis industry employed about 321,000 full-time equivalent jobs in 37 states in the United States [Barcott et al. 2021]. Understanding the nature of work and potential hazards involved in the growth, harvesting, processing, and packaging of cannabis products are important steps in improving occupational safety and health for this fairly new industry. The National Institute for Occupational Safety and Health (NIOSH) has completed two previous health hazard evaluations [NIOSH 2017, 2019] in this regard.

Building

The facility was a single building that housed office and operations areas for two brand names of cannabis that were owned by the same parent company (Side A and Side B). Each brand grew, harvested, dried, trimmed, and packaged bulk product in separate areas of the facility.

Employee Information

Each side of the facility employed cultivation and harvesting employees who worked full time. The facility also had a contract with a staffing agency to supply trimming employees for each side of the facility. All employees worked a single, 8-hour shift and were not unionized. Trimming did not occur every day, so those employees were not always at the facility. We visited the facility when trimming operations were occurring in addition to cultivating and harvesting. Additionally, trimming staffing varied due to availability and scheduling dictated by the staffing agency that managed this pool of employees.

Process Description

This facility cultivated, harvested, trimmed, and packaged bulk cannabis. The bulk product was either sold to other companies or moved to further processing facilities. The health hazard evaluation (HHE) request did not extend to other processing facilities. Employees and management told us that production levels and conditions we observed were representative of normal operations at this facility.

Employees in this type of environment may be exposed to a variety of plant-derived materials (e.g., leaves, buds, sap/exudate, flowers, and pollen) when handling the plant during cultivation and processing procedures. They can also encounter cannabinoids and other contaminant- and plant-pathogen sources such as bacteria and fungi.

Cultivation

The cultivation process began in the clone room where employees removed cuttings from mature donor plants to create clones, or seedlings. The clones grow to be new individual plants that were genetically identical to the donor plants. As the clones grow larger, they were moved out of the clone room and into the cultivation areas where they were cared for until mature and ready for harvest. There were two large, open areas of the facility where cultivation took place. In each area, multiple sets of plants were being grown. Each set had dozens of plants of the same type that were cloned and grown together at the same time.

In the cultivation areas, employees performed a variety of tasks aimed to promote growth and inhibit pests during the cultivation cycle. Employees removed leaves from plants so that the plant would dedicate energy into producing flowers instead of leaves. When the plants reached certain heights, plastic trellis netting was attached to the grow areas to promote vertical growth and prevent plants from falling over when top-heavy. Nutrients and pesticides were applied according to a proprietary schedule and according to manufacturer's recommendations.

Harvesting

Once a set of plants reached maturity, they were harvested. Harvesting involved cutting the plastic trellis nets that held up the plants and removing large stems containing the cannabis flowers from the plants. The stems were hung on garment racks in preparation for transfer to the drying room. After harvesting was complete, the harvesting crew cleaned the area in preparation for a new set of plants to be grown.

Drying

After harvest, the stems of flowers were transferred to the drying rooms. Stems were hung to dry before trimming in two drying rooms on each side of the facility. An ozone generator was used to generate ozone in the drying rooms periodically throughout the drying process. The ozone generation was used to prevent microbial growth on the plants while they were drying.

Trimming

After the flowers were dried, employees removed the stems from the drying room and trimmed the flowers from the stems by hand. The trimmed flowers were packaged in bulk and brought to the vault for storage before leaving the facility. There was an ozone generator in the vault that was used in a similar way to the ones in the drying rooms.

Section B: Methods, Results, and Discussion

The objectives of this evaluation were to observe work practices, measure employee exposures to potential hazards, and learn about employees' general safety and health concerns to provide recommendations for improving employee safety, health, and well-being in the cannabis industry.

Methods: Observations of Work Processes, Practices, and Conditions

During our two visits to the facility, we observed the work processes, PPE use, and workplace conditions of employees as they performed cultivating, harvesting, drying, and trimming tasks.

Results: Observations of Work Processes, Practices, and Conditions

Cultivation

All cultivation and harvesting employees changed into employer-provided scrubs prior to entering the cultivation areas of the facility. Scrubs were laundered by the employer. All employees were given sunglasses as eye protection from the grow lights. This facility used high pressure sodium (HPS) grow lights throughout the cultivation areas. During our first visit, we noticed that the sunglasses being provided to employees were not specifically chosen based on their ability to filter out the specific wavelengths of light produced by the grow lights. We recommended that the company purchase sunglasses that were appropriate for protection from grow lights. During our second visit, the company had purchased hydroponics grow room light glasses for employees. The packaging for the glasses stated that the glasses provided UV light protection, reduced glare, and were "perfect for using under HPS… lighting systems." We were unable to determine whether the claims of the manufacturer were accurate. There was no testing information available on the manufacturer's website to support these claims.

During leaf removal, some employees wore long sleeve shirts under their scrubs and told us it was to protect their skin from contacting the plants while removing leaves. The employer did not provide the long sleeve shirts. We were told that nutrients and pesticides were added periodically to the plants according to the manufacturer's recommendations. There was a table posted near the nutrient and pesticide storage areas that included information about each product (e.g., concentration, protective equipment during application).

We did not observe pesticide application during our visits. We learned that all pesticide application was performed by employees who were certified to apply pesticides by the state Department of Agriculture. We were told by employees and management that pesticides were only applied after normal business hours. Employees were issued one elastomeric full-face respirator by the company and were responsible for cleaning and maintenance. The company relied on the state Department of Agriculture pesticide applicator certification and did not have a respiratory protection program (i.e., did not provide medical clearance, fit testing, or training about respiratory protection to employees). We observed respirators hung on the wall near the pesticide/nutrient mixing area in between uses. We saw both P100 and OV cartridges in the facility. No combination P100/OV cartridges were evident. There was no changeout schedule for cartridges. After our first visit, we recommended that the company improve respiratory protection practices, including creating a written program. During the second visit, the company had improved storage practices for the elastomeric full-face respirators.

We noted the lack of eye wash stations near the pesticide/nutrient mixing areas during our first visit. During our second visit, the company had purchased eye wash bottles to place in the two pesticide/nutrient mixing areas.

We observed employees repotting plants during one of our visits. During this task, soil was placed in a children's pool elevated about 12–18 inches off the ground. The pool was placed on a wooden pallet that was on top of overturned pots. Empty pots and plants were staged around the pool. Employees were observed rapidly placing the plants into the pots and filling the pots with soil from the pool. To accomplish this task, employees were bent over to access the soil and used their hands and forearms to quickly scoop soil into the pot (Figure B1).

Figure B1. Employees repotting plants using soil from an elevated children's pool. Photo by NIOSH.

On both sides of the facility were several large ventilation units that ran continuously to mix the air inside the facility. These units were large, ductless, open-building heating and cooling equipment. We were informed that the units were intended only to mix and condition the air within the facility, not to filter contaminants. The units appeared to contain large filter banks. A handwritten note on the side of the units indicated 44 filters, sized 20 inches × 20 inches × 2 inches, and 22 filters, sized 20 inches × 12 inches × 2 inches; however, we were informed that filters were not used in these units. We learned that the employer washed the intake grates periodically but had never bought filters for the units.

Harvesting

The plastic trellis netting needed to be cut away from the plants before and periodically during the harvesting process. The cut plastic was placed on the ground wherever it was cut, presenting a tripping hazard for employees. During the harvesting process, employees cut several large stems off the plants and brought them to a folding table for weighing. Employees were observed repeatedly bending over to access the lower parts of the plastic trellis netting and the lower stems on the plants. The harvest we observed was for plants with pots placed directly on the ground. Other sets of plants were on raised cultivation beds. We were told that there was no difference between the cultivation setups, and that some sections of the facility just had raised cultivation beds. The stems were hung on a garment rack after being weighed and logged into the computer system. Once the harvest was complete, the garment racks were moved into the drying rooms.

After the harvest, multiple steps were involved in cleaning up the area previously occupied by the plants. First, the plastic trellis netting was placed in trash cans. Then the growing pots, still full of soil, were placed on a cart and brought to another area of the facility where they were emptied. The pile of soil from the pots was either reused for future planting or disposed of, depending on the condition. We observed employees dry sweeping the floor to clean up dirt and debris from the harvesting activities. Harvesting did not occur every day, and the harvest we observed did not last the full shift.

After the growing pots were emptied of soil, they were brought to another area of the facility to be washed and rinsed in preparation to be reused. Employees who were washing the pots were wearing work scrubs, latex or nitrile gloves, and sunglasses. The cleaning product contained 34% hydrogen peroxide. Employees were observed pouring the cleaning product into the pots and scrubbing them with short-handled brushes. Employees needed to reach their hands into the pots when scrubbing. Pots were rinsed out with clean water from a hose and all runoff was captured by a drain in the floor. The scrubbing and rinsing tasks produced visible splashes periodically during the process.

Drying

Each drying room had an ozone generator inside. The generator was operated by plugging it in and then turning a knob to start the generation. The knob could be turned to run for a specific period, or it could be set to be continuously operational. The process we observed involved all generators set to continuously operate. The generators were plugged into an analog electrical timer that turned the generator on for a set amount of time overnight and turned it off before employees arrived for their shift the following day. We learned from employees that power outages could inadvertently cause the timer to be inaccurate (i.e., the analog timer did not account for power outages). When this occurred, employees told us that the ozone generators would run while employees were in the building instead of overnight. It was unclear how often this occurred, but many employees were concerned about potential ozone exposures.

Trimming

The trimming rooms were set up with multiple eight-foot folding tables situated around the room (Figure B2). Each table had chairs arranged around it. The contractors who were assigned to trimming tasks either stood or sat around the table and used hand cutters to trim the flowers from the stems. Stems were discarded in one pile while the trimmed flowers were placed in a tote. The trimming process was a highly repetitive task where most trimming employees were continuously snipping flowers from stems and placing them into the tote. Employees had a 45-minute lunch break and two scheduled 15-minute personal breaks per shift. None of the chairs or tables had adjustable heights and the trimming employees varied considerably in height. When trimming employees were standing at the tables, many needed to bend over to pick up stems and again to place flowers into the totes. When trimming employees were seated, many would rest their forearms on the edges of the tables. The table

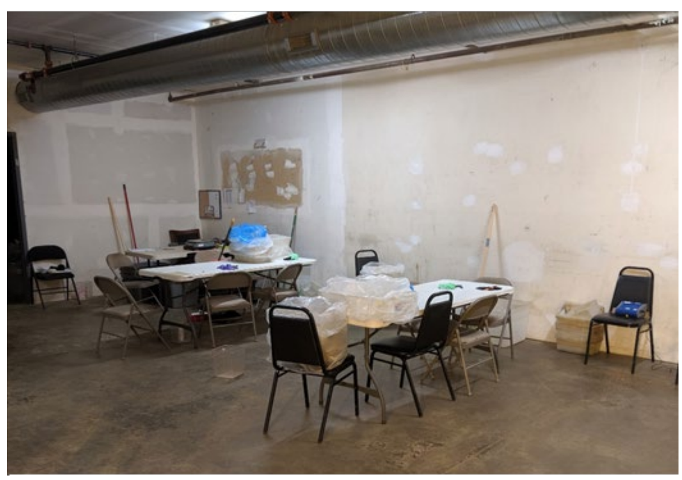


Figure B2. One of the trimming areas. Each table can accommodate four to six trimming employees. Photo by NIOSH.

edges were square (i.e., not rounded) and did not have padding along the edges where trimming employees would rest their forearms and elbows.

At the end of each shift, trimming employees used 90% isopropyl alcohol solutions to clean work surfaces. The alcohol was applied using a spray bottle and then paper towels were used to wipe the sprayed surfaces. Employees told us that they were concerned about their exposures to alcohol vapors during the cleaning process.

When the flower tote was full or when the trimming employees were done with their allotted stems, employees brought the tote to a supervisor at a table in the corner for the product to be weighed and logged into the system. There was also one trimming machine that could be used to process the trimmed flowers (Figure B3). When in use, we noted that the safety switch was taped down so the machine would run when the cover was not closed. We were informed that the employees needed to be able to see the flowers and to move the flowers around while the machine was in operation. This process required employees to stick their hands into the machine while it was rotating.

Figure B3. An employee operating the trimming machine with the lid opened while the machine is operating. Photo by NIOSH.

We were not permitted to step into the vault during our visits, but we were able to observe that there was an ozone generator in the vault. We learned that this ozone generator was used in a similar manner to the ones in the drying rooms. The generator was attached to an analog electrical timer that turned the generator on for a set amount of time overnight and turned it off before employees arrived for their shift the following day.

Methods: Exposure Assessment

Endotoxin

We collected personal air samples on cultivation and harvesting employees using three-piece, 37-millimeter-diameter close-faced cassettes with 0.45-micrometer (µm) pore size preloaded polycarbonate filters. The sampling pumps were calibrated at a flow rate of 2 liters of air per minute. Each sample was analyzed for endotoxin using a recombinant Factor C assay method (HyGlos EndoZyme® rFC Assay). The assay was a quantitative endpoint florescence test used to measure gram-negative bacterial endotoxin.

We collected personal air samples for endotoxin on 20 employees during their entire work shift (10 employees from each side of the facility). All cultivation and harvesting employees were invited to participate in the sampling. Samples were paused and pumps removed from employees during breaks. For these analyses, the reporting limit was 0.40 endotoxin units (EU) per sample.

Cannabinoids

Surface wipe samples were collected in production and nonproduction areas of the facility and analyzed for Δ9-THC, Δ9-THCA, CBD, and CBN. Where possible, two samples were taken in each location. The second sample was taken directly adjacent to the first sample whenever possible. Each sample was taken with a cotton twill wipe moistened with 3 milliliters of isopropanol. All samples were taken using a disposable 100-square-centimeter (100 cm^2) template. If the template was not feasible (e.g., the surface was an irregular shape that did not lend itself to using the template), approximately 100 cm^2 of surface was wiped for the sample.

Each pair of samples were analyzed using two methods, one for each sample. One sample was analyzed for Δ9-THC using a contract laboratory's internal method. The method used high performance liquid chromatography and tandem mass spectrometry with a limit of detection of 5 nanograms (ng) per sample. The second sample was analyzed for Δ9-THC, Δ9-THCA, CBD, and CBN using a modified method [Ambach et al. 2014]. The modified method used high performance liquid chromatography with diode-array detection with a limit of detection of 2 micrograms (µg) per sample for each analyte.

Fungi

Genomic DNA Extraction from Air Samples

General area air samples (n = 14) were collected using the NIOSH BC251 two-stage air sampler: 7 samples from each side (Side A and Side B) of the facility. All samples were processed for fungal DNA extraction using the Roche High Pure Polymerase Chain Reaction (PCR) Template kit as previously described in earlier studies [Green et al. 2017; Green et al. 2018]. Each stage obtained from the NIOSH two-stage sampler was combined. The after filter was sectioned into six pieces and placed into a 2-milliliter (mL) reinforced tube containing 300 milligrams of glass beads. We placed the tubes in liquid nitrogen for 30 seconds and processed two times in a bead mill homogenizer for 30 seconds. The Roche kit lysis buffer (650 microliters [µL]) was then sequentially added to the first and second stage tubes and vortexed to collect the deposited bioaerosols. The lysis buffer was then added to the 2 mL reinforced tube containing the macerated filter material. We processed the tubes again in a bead mill homogenizer for 30 seconds and then centrifuged for 1 minute at 20,000 × *g*, a measure of relative centrifugal force. We collected the supernatant and incubated with 40 µL Cell Lytic B lysis reagent (Sigma Aldrich) for 15 minutes at 37°C. We mixed the sample with the Roche kit binding buffer (200 µL) and proteinase K solution (40 µL) and incubated at 70°C for 10 minutes. We washed and eluted the genomic DNA from the samples as recommended by the manufacturer.

Fungal ITS Region Amplification, Cloning, and Sanger Sequencing

We amplified the fungal Internal Transcribed Spacer (ITS) regions using a procedure modified from methods that were described in previous studies [Green et al. 2017; Green et al. 2018]. Briefly, the fungal ITS1 region sequences were amplified with the primer pair ITS1F (CTTGGTCATTTAGAGGAAGTAA) and ITS2aR (GCTGCGTTCTTCATCGATGC) using Platinum Taq DNA polymerase (Invitrogen) and 5 µL of genomic DNA template. Three replicate PCR reactions (50 µL) were run for each sample and were then combined and purified with a Qiagen PCR purification kit according to the manufacturer's instructions.

We cloned the fungal amplicons into the pDRIVE vector using a Qiagen PCR cloning kit and then generated clone libraries by transforming cloned plasmids into chemically competent *Escherichia coli* cells as previously described [Green et al. 2017]. Based on the fungal gDNA yield, we selected 12–48 positive colonies per air sample (as determined colorimetrically by the inactivation of the lacZ gene) and cultured the colonies for 16 hours at 37°C in liquid Luria-Bertani media containing 100 µg/mL of ampicillin. The cells were centrifuged at 1800 × *g* (relative centrifugal force) for 10 minutes and the pellets were resuspended in 200 µL of 15% glycerol and sent to Genewiz, Inc., for Sanger sequencing of the fungal ITS1 insert.

Inserts were sequenced in both directions, allowing for sequence analysis of the full ITS1 region. We downloaded the sequencing results as ".ab1" trace files and the forward and reverse sequences were trimmed and assembled using Biomatters Geneious R7 Software. Sequence data were then clustered into operational taxonomic units with MOTHUR software version 1.32.1 using a 97% similarity cutoff as described previously [Green et al. 2017]. Sequences representative of each operational taxonomic unit were then used in a Basic Local Alignment Search Tool search against the National Center for Biotechnology Information sequence database.

Particulates

We measured particulates in three areas of the facility for a full shift using DustTrak™ DRX 8533 Aerosol Monitors (TSI, Inc.). Two monitors were in the trimming rooms, one on a table near the trimming machine on Side A, and one near the middle of the trimming room on Side B. The third monitor was on a folding table that was temporarily set up during a harvest. All monitors were set to log particle concentrations every 60 seconds in different size groups: particulate matter (PM) smaller than 1 µm (PM_1), PM smaller than 2.5 µm ($PM_{2.5}$), respirable (less than 4 µm), PM smaller than 10 µm (PM_{10}), and total PM (less than 100 µm).

Noise

We measured area noise levels in different parts of the production areas using a Quest 3M Model 2400 calibrated, battery-operated, type-2 sound level meter. We focused on areas where employees were working, including close to the ventilation units, in the trimming rooms, and in areas where music was being played by a portable speaker.

Results: Exposure Assessment

Endotoxin

Endotoxin was detected in all samples (Table C1). On Side A, exposures ranged 6–980 endotoxin units per cubic meter of air (EU/m^3). On Side B, exposures ranged 11–660 EU/m^3. Four employees (40%) from each side were exposed to endotoxin above the Dutch Expert Committee on Occupational Standards (DECOS) limit of 90 EU/m^3 [DECOS 2010]. The United States does not have an occupational exposure limit (OEL) for endotoxin. The DECOS limit is the most relevant available OEL for our results.

Cannabinoids

Surface wipe samples for cannabinoids were collected using two methods in eight locations throughout the facility (Table C2). One method analyzed samples for Δ9-THC only. The second method analyzed samples for multiple cannabinoids simultaneously (Δ9-THC, Δ9-THCA, CBD, and CBN).

For the Δ9-THC only method, all surface wipe samples had detectable levels of Δ9-THC. The surface wipe results ranged 1–91 micrograms per 100-square-centimeters (µg/100 cm^2) in production areas and from 0.035–0.93 µg/100 cm^2 in nonproduction areas.

For the method analyzing samples for multiple cannabinoids simultaneously, three of five surface wipe samples in production areas had detectable levels of Δ9-THC (range: not detected–110 µg/100 cm^2). Δ9-THCA was detected in all samples taken in production areas (range: 25–1,000 µg/100 cm^2) and in two of three samples taken in nonproduction areas (range: not detected–15 µg/100 cm^2). CBD and CBN were detected in low amounts in production areas. We did not detect Δ9-THC, CBD, or CBN in nonproduction areas using this method.

Fungi

A total of 226 fungal DNA sequences that clustered into 87 operational taxonomic units were identified in the 14 area air samples. There was low to no fungal DNA yield in the field and media blanks. As shown in Figure B4, the identified fungi were placed into three major fungal phlya: Ascomycota (56%), Basidiomycota (43%), and Zygomycota (1%). The most prevalent fungal orders in the phylum Ascomycota were Erysiphales (19%), plant pathogens often referred to as powdery mildews, and Eurotiales (12%), containing ubiquitous fungi, like *Aspergillus* and *Penicillium* species (Figure 4B). Within the phylum Basidiomycota, 13% of the fungi were placed in the order Sporidiobolales (Figure 4B), with most belonging to the genus *Rhodotorula* (Table C3). The most abundant species making up almost 20% of all fungal sequences detected in the area samples was *Golovinomyces spadiceus*, a powdery mildew in the order Eryisiphales, followed by species in the genera *Rhodotorula*, and *Penicillium* (Table C3). *Cladosporium* species, often encountered in outdoor environments, were also prevalent in some samples.

More fungal DNA was obtained from area samples collected from Side A of the facility (169 of the 216 sequences) than those collected from Side B. The samples with the highest number of fungal sequences identified were obtained near the trim room tables and the grow area closest to harvesting procedures (Table C4).

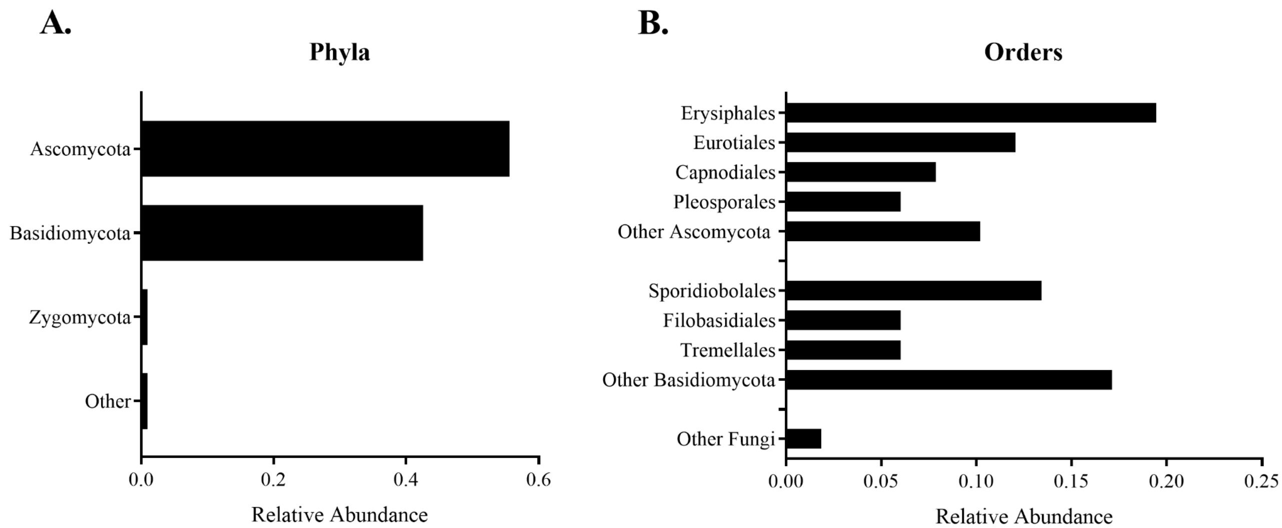


Figure B4. Relative abundance of fungal phyla (A) and orders (B) identified in area air samples.

Particulates

Particle mass concentrations were low in all three areas, across all size ranges (Table C5). Respirable dust ranged 0.014–0.15 milligrams per cubic meter of air (mg/m^3) on the Side A harvest table, 0.015–0.13 mg/m^3 in the Side A trimming area, and 0.012–0.11 mg/m^3 in the Side B trimming area.

Noise

We made area sound measurements while work was being performed in the cultivation and trimming areas of the facility. The ventilation units were operating, and music was being played in both trimming rooms and where harvesting was taking place. Many employees were observed wearing earbud headphones while working in these areas. The Side A cultivation area ranged 75–83 decibels, A-weighted (dBA). The Side A trimming room averaged 83 dBA. The Side B cultivation area ranged 73–83 dBA. The Side B trimming room averaged 74 dBA. The measured exposures cannot be compared to OELs since they are not personal exposure measurements collected as full-shift time-weighted averages. However, the upper end of the sound levels we measured were slightly below the NIOSH recommended exposure limit (REL) of 85 dBA and the OSHA action level (AL) of 85 dBA.

Methods: Confidential Medical Interviews

We completed semi-structured, confidential medical interviews with employees performing cultivation and harvesting duties and employees performing trimming. The results of these employee groups are reported separately (i.e., no comparisons are made between groups) in this report due to the differences in job roles, tasks, and work locations).

Supervisors coordinated bringing employees one by one to a low traffic area in the workplace which had been identified as suitable for maintaining privacy during the interviews. When an employee arrived, we explained the purpose of the HHE and asked if they would like to participate in a confidential interview about workplace safety and health. Those who refused were thanked for their time and returned to work. Interviews averaged about 15 minutes each.

The interviews included questions to assess the following:

- Job tasks (cultivation and harvesting employees only): Employees were read a list of tasks common to the cultivation and harvesting of cannabis and were asked to indicate (yes/no response) whether they performed each task as part of their job duties. Employees were also given the opportunity to identify additional tasks not on the list (open-ended response format).
- PPE use: Cultivation and harvesting employees were asked, "If you mix and/or apply pesticides as part of your duties, what type of PPE do you wear?" (open-ended response format). Trimming employees were asked, "What kind of PPE do you regularly wear on the job?" (open-ended response format).
- Health and safety concerns: Employees were asked, "Do you have any work-related health or safety concerns?" (yes/no response), followed by, "If yes, describe" (open-ended response format).
- Health symptoms: Employees were read a list asking them to indicate whether they had experienced any work-related health symptoms over the past 4 weeks (yes/no response). Employees were also given the opportunity to identify additional symptoms not on the list (open-ended response format).
- Perceptions of physical working conditions and psychosocial factors: We used a combination of items from an occupational health survey [Weel and Fortuin 1998] and items developed specifically for this HHE to ask if employees had concerns about physical working conditions and psychosocial factors at work (yes/no response).
- Job stress: Employees were read the following definition of job stress: "NIOSH defines *job stress* as the harmful physical and emotional responses that occur when the requirements of the job do not match the capabilities, resources, or needs of the worker." They were then asked to rate their overall level of job stress on a scale from 0 (no stress at all) to 10 (severe stress). Responses of 0–3 indicated low job stress, 4–6 indicated moderate job stress, and scores of 7 or greater indicated high job stress [Clark et al. 2011]. Employees were then asked to identify major sources of job stress (open-ended response format).

Employee responses were transcribed onto paper, which were later recorded in a spreadsheet maintained on a secure server at NIOSH. Employee names were not recorded to protect confidentiality. All employee responses to interview questions are protected to the greatest extent possible by the Privacy Act of 1974 and the Freedom of Information Act.

Results: Confidential Medical Interviews

Employee Information

We interviewed 25 of 25 (100%) cultivation and harvesting employees present during our visit. Of these, 24 (96%) were male. The average age was 30 years (range: 22–47 years), the average amount of time working at the facility was 1 year, 4 months (range: 2 days–5 years), and the average number of hours worked a week was 37 hours (range: 30–45 hours).

We interviewed 25 of 30 (83%) trimming employees present during our visit. Of these, 19 (76%) were male. The average age of these employees was 31 years (range: 21–60 years), the average amount of time working at the facility was 10 months (range: 2 days–2.5 years), and the average number of hours worked a week was 31 hours (range: 5–40 hours).

Job Tasks

Cultivation and harvesting employees had job titles of grow technician, cultivation manager, and facility manager. We asked these employees to indicate whether a list of common job tasks was part of their responsibilities. These tasks included cultivation (n = 24; 96%); harvesting (n = 23; 92%); topping (n = 23; 92%); transplanting (n = 23; 92%); examining plants (n = 23; 92%); staking plants; (n = 23; 92%); waste disposal (n = 22; 88%); pest control (n = 22; 88%); feeding (n = 22; 88%); cloning (n = 21; 84%); pesticide application (n = 20; 80%); flushing plants (n = 16; 64%); inventory (n = 10; 40%); and maintenance (n = 16; 64%). When asked an open-ended question about "other" job tasks, some employees reported trimming and super-cropping of plants.

A supervisor informed us that all trimming employees had the same job title of "trimmer" and were expected to complete the same job tasks, which included trimming flowers from stems, fanning and bucking plants, quality control, and cleaning tools and workspaces.

Personal Protective Equipment

Of the 20 cultivation and harvesting employees who reported mixing or applying pesticides, all (100%) reported wearing a Tyvek® suit, nitrile and rubber gloves, booties, a head sock, respirator, and face shield during these tasks. Some employees reported that they wore personal sunglasses to reduce light exposure on the floor. Also, some employees reported wearing earbud headphones to drown out the noise of the ventilation unit(s).

All 25 (100%) of the trimming employees reported wearing nitrile gloves, 16 (64%) reported wearing a bandanna or dust mask, and 6 (24%) reported wearing scrubs while working.

Work-related Safety Concerns

Of the 25 cultivation and harvesting employees interviewed, 10 (40%) indicated that they had work-related safety concerns. They included noise (n = 6; 24%); bright lights (n = 4; 16%); and exposure to pesticides (n = 3; 12%). Other concerns were reported by two or fewer employees and are not described to maintain employee confidentiality.

Seventeen of 25 (68%) trimming employees indicated they had work-related safety concerns. They included indoor air quality (n = 6; 24%); exposure to pesticides (n = 4; 16%); using alcohol to clean workstations (n = 4; 16%); exposure to ozone (n = 3; 12%); and communication concerns (n = 3; 12%). Other concerns were reported by two or fewer employees and are not described to maintain employee confidentiality.

Work-related Health Symptoms

Table C6 includes the frequency and percentage of employees who reported "yes" to experiencing work-related health symptoms in the past 4 weeks. The five most frequently reported symptoms among cultivation and harvesting employees were stuffy nose or sinus problems (n = 10; 40%); runny nose (n = 9; 36%); back pain (n = 9; 36%); rash on skin (n = 7; 28%); and red or irritated eyes (n = 6; 24%).

The five most frequently reported symptoms among trimming employees were stuffy nose or sinus problems (n = 18; 72%); back pain (n = 15; 60%); headaches (n = 13; 52%); runny nose (n = 12; 48%); and hand/wrist pain (n = 11; 44%).

Physical Working Conditions and Psychosocial Factors

Table C7 includes the physical working conditions that employees indicated made them uncomfortable at work. The most frequently reported conditions that made cultivation and harvesting employees uncomfortable at work were bright light (n = 18; 72%); dust/dirt (n = 17; 68%); and heat (n = 12; 48%). The most frequently reported conditions that made trimming employees uncomfortable at work were dust/dirt (n = 16; 64%); lack of fresh air (n = 15; 60%); lengthy periods of being in the same physical position (n = 14; 56%); bad smells/odors (n = 13; 52%); and loud noise (n = 13; 52%).

Table C8 shows the number of employees who responded "yes" to the psychosocial items. Overall, most cultivation and harvesting employees reported positive perceptions of psychosocial factors at work. Some areas that may need improvement among these employees are related to the responses to "is your work made more difficult due to other people not doing their job properly?" (n = 19; 79%); "do you regularly work under short deadlines?" (n = 12; 48%); "is your work made more difficult by other people being absent?" (n = 9; 36%); and "do you have a lot of say or get to make many decisions as part of your job?" (n = 9; 36%).

Overall, most trimming employees reported positive perceptions of psychosocial factors at work. Some areas that may need improvement among these employees are related to the responses to "is your work made more difficult due to other people not doing their job properly?" (n = 19; 76%); "is your work well organized?" (n = 14; 56%); "do you have a lot of say or get to make many decisions as part of your job?" (n = 8; 32%); "do you believe you were trained well for your job?" (n = 16; 64%); and "do you have enough variation in your work?" (n = 16; 64%).

Job Stress

The average job stress score for cultivation and harvesting employees was 2.6 (range: 0–7, n = 25), indicating low job stress overall. On the basis of individual stress scores, 16 (64%) employees indicated low job stress, 8 (32%) indicated moderate job stress, and one (4%) indicated high job stress. Eighteen (72%) provided an open-ended response about major sources of job stress. The most frequently reported sources of job stress were the growth of the company (n = 4; 16%); increased responsibilities (n = 4; 16%); and being concerned about the plants (n = 3; 12%). Other stressors were reported by two or fewer employees and are not described to maintain employee confidentiality.

The average job stress score for trimming employees was 3.1 (range: 0–7; n = 25), indicating low job stress overall. On the basis of individual stress scores, 13 (54%) employees indicated low job stress, 9 (38%) indicated moderate job stress, and 2 (8%) indicated high job stress. Twenty-two (88%) provided an open-ended response about major sources of job stress. The most frequently reported sources of job stress were changes in procedures (n =10; 40%); communication issues (n = 7; 28%); perceived poor product quality (n = 4; 16%); lack of proper equipment (n = 4; 16%); working with inexperienced coworkers (n = 3; 12%); and perceived lack of trust from the company (n = 3; 12%). Other stressors were reported by two or fewer employees and are not described to maintain employee confidentiality.

Discussion

Exposures to airborne endotoxin come from soil- and plant-disturbing activities. During our evaluation we observed employees dry sweeping after a harvest, rapidly moving soil into pots when repotting, and bending over the pool of soil as they used their hands and forearms to move soil while repotting. All of these activities, in addition to trimming, removing leaves, and harvesting, will increase the chance of exposure to airborne endotoxin. When disturbed soil or plants can release endotoxin-containing bacteria into the air. Some potential opportunities to reduce endotoxin exposures would be to eliminate or minimize dry sweeping and reduce soil disturbance when repotting plants.

The airborne endotoxin concentrations at the facility were similar to those found at an indoor flower greenhouse (range: 0.84–1,100 EU/m^3) but much lower than those found in other agricultural settings. These settings include two indoor herb processing plants (median endotoxin concentration: 3×10^5 EU/m^3); four peppermint and nine chamomile herb farm indoor processing operations (median for endotoxin peppermint farms: 1×10^6 EU/m^3; median endotoxin for chamomile farms: 1.8×10^4 EU/m^3); and an indoor hemp processing plant (mean endotoxin concentration: 1.9×10^4 EU/m^3) [Dutkiewicz et al. 2001; Fishwick et al. 2001; Skórska et al. 2005; Thilsing et al. 2015].

The main way cannabinoids are differentiated is by the degree of their psychoactivity. Δ9-THCA, CBD, and CBN are not psychoactive substances, meaning they do not change a person's mental state by affecting the way the brain and nervous system work. Δ9-THC is the psychoactive component of cannabis. The long-term health effects of occupational exposures are currently unknown. The differences between occupational exposures to psychoactive cannabinoids and non-psychoactive cannabinoids are also unknown.

We detected cannabinoids on both production and nonproduction surfaces, though nonproduction surfaces had lesser concentrations detected. Cannabinoids are expected to be found in production areas. Detecting cannabinoids in nonproduction areas indicates that cleaning and hand hygiene could be improved to prevent contaminating nonproduction areas when leaving production areas. While collecting surface wipe samples, efforts were made to ensure that the majority of samples were adjacent. However, because of presumed unequal distribution of cannabinoids across surfaces, even when directly adjacent, we cannot directly compare results between the two methods. Δ9-THCA concentrations were higher than Δ9-THC concentrations in all surface wipe samples except for one sample collected on the surface of a table in the lobby of the building. A previous NIOSH HHE report suggested that in cannabis cultivation workplaces, Δ9-THCA concentrations would be present in higher concentrations than Δ9-THC concentrations because the Δ9-THCA would not have been decarboxylated through heat or aging [NIOSH 2017]. This facility was focused on the cultivation, harvest, and trimming of cannabis and not on further processing, so these surface wipe results are consistent with other evaluations in similar workplaces.

The most abundant fungal species detected at the trim room table was *Golovinomyces spadiceus* on Sides A and B of the facility. *G. spadiceus* is a plant pathogen that causes powdery mildew on several plants, such as okra [Moparthi et al. 2018], goldenstar [Trigiano et al. 2017], Coreopisis 'Full Moon' [Dugan 2013], and wild sunflowers [Félix-Gastélum et al. 2019]. *G. spadiceus*, along with other Golovinomyces species such as *G. cichoracearum*, have also been known to cause powdery mildew on *Cannabis sativa* plants [Pépin et al. 2018; Punja et al. 2019; Szarka et al. 2019]. In addition, *Pencillium olsonii*, which was among the penicillium species detected in area samples, has also been shown to cause bud rot on *C. sativa* [Punja et al. 2019]. Golovinomyces species were detected in previous Cannabis grow facilities, although not as abundantly as was detected in the current facility, along with other plant pathogens like *Botrytis cinerea* that belong to the same Leotiomycetes class [Green et al. 2018]. The health effects following exposure to Golovinomyces species have not been studied.

Our results from particulate monitoring indicate that there are dust exposures during trimming and harvesting activities, but there are no specific OELs that can be used to evaluate these exposures. OELs exist for general dust, but those limits are intended for nuisance dust that is known to not contain harmful components. Additionally, area samples cannot be compared to OELs since OELs are based on personal exposure levels. In this evaluation, we sampled areas where we expected work processes may produce particulates, and we were able to confirm that this was the case. The particulates produced during these tasks are likely a major mechanism by which endotoxin and cannabinoids are released when soil and plant matter is disturbed.

Area noise measurements indicated that at times the sound levels we measured reached levels approaching the NIOSH REL and OSHA AL levels of 85 dBA. If noise levels increased in these work areas the possibility of noise overexposure would likewise increase. We found that noise levels were greater near the ventilation units and in areas where loud music was playing. If an employee works in one of these areas and is also wearing headphones to listen to music during work, the noise exposures from those headphones could exceed exposure limits because the volume of the headphones would likely need to be raised to compete with the external noise. Further, our measurements were short-term, area measurements and cannot accurately capture individual exposures. Our goal was to characterize noise levels across these work areas and identify whether there was potential for overexposure to noise.

Many of the tasks we observed included repetitive motion and awkward postures. When repotting plants employees were observed to be bending over the pool of soil to add soil to the pots. Employees then added a plant and more soil to completely fill the pot before moving it to the floor and beginning the process again. Additionally, when removing leaves, employees needed to bend over to reach those on the lower parts of the plants, increasing the risk for lower back injury. Our observations and findings indicate that the trimming employees have exposures to highly repetitive work, most notably during hand trimming activities. These exposures increase their risk of musculoskeletal disorders. The trimming area also does not have adjustable tables or chairs, further increasing the risk for musculoskeletal disorders.

The confidential medical interview results provide a "snapshot" of employee safety and health concerns during our evaluation. It is important to communicate and receive input about work and well-being from employees on a regular basis, especially during times of change or company growth when policies and procedures may be in fluctuation. Assessing, understanding, and monitoring employee well-being and work concerns can help employees and employers work together to design work and employment conditions in a way that will prioritize safety and improve physical and psychological outcomes. Additional information on policies, programs, and practices that integrate protection from work-related safety and health hazards with promotion of injury and illness-prevention efforts to advance worker well-being can be found through the NIOSH *Total Worker Health*™ program at www.cdc.gov/niosh/twh.

Limitations

This evaluation was subject to several limitations. Industrial hygiene sampling could only document exposures and conditions in the locations evaluated and on the days which the evaluation occurred. These results may not have been representative of conditions during other days. Medical interviews were also subject to similar limitations. We were only able to document concerns and symptoms that were reported to us during our evaluations by current employees who chose to participate. We were not able to include information from employees who had left the workforce or were not present at the facility at the time of the evaluation. Interviews may have been impacted by selection, recall, and social desirability biases.

Conclusions

Employees were concerned about potential exposures to ozone, bright lights, and pesticides, among others. Our air sampling found that employees were exposed to endotoxins. We also found that trimming employees have exposure to highly repetitive work that increases their risk for musculoskeletal disorders. We recommended that the workplace reduce exposures to endotoxins, cannabinoids, ozone, light, and noise. We also recommended that they reduce the risk of musculoskeletal disorders and obtain regular input from employees about workplace safety, health, and well-being issues.

Section C: Tables

Table C1. Personal air sample results for endotoxin exposures

Job title	Sample duration (minutes)	Endotoxin concentration (EU/m^3)	Exceeds occupational exposure limit?
Side A			
Cultivator 1	333	220	Yes
Cultivator 2	347	56	No
Cultivator 3	355	85	No
Cultivator 4	329	6	No
Cultivator 5	333	980	Yes
Cultivator 6	365	110	Yes
Cultivator 7	331	430	Yes
Cultivator 8	329	12	No
Cultivator 9	339	16	No
Cultivator 10	39*	17	No
Side B			
Cultivator 11	341	140	Yes
Cultivator 12	333	61	No
Cultivator 13	335	63	No
Cultivator 14	336	11	No
Cultivator 15	339	120	Yes
Cultivator 16	328	150	Yes
Cultivator 17	335	660	Yes
Cultivator 18	340	16	No
Cultivator 19	61*	46	No
Cultivator 20	343	78	No
DECOS limit		90	

*These employees left work early.

Table C2. Surface wipe sampling for cannabis compounds (μg/100 cm^2)

Location	Δ9-THC only method	Cannabinoid method*			
	Δ9-THC	Δ9-THC	Δ9-THCA	CBD	CBN
Side A Production area					
Trimming room supervisor desk	56	71	530	ND	[4.2]
Table near harvest activities	3.7	ND	140	[3.4]	8.5
Side B Production area					
Trimming room table	91	110	1,000	[2.9]	17
Table outside of trimming room	18	25	280	[3.2]	[4.2]
Table near repotting activities	1	ND	25	ND	ND
Nonproduction areas					
Table in lobby sitting area	0.035	ND	ND	ND	ND
Breakroom countertop	0.45	ND	15	ND	ND
Breakroom refrigerator handle†	0.93	ND	12	ND	ND

ND = not detected

[ ] = values in brackets are between the limit of detection and limit of quantification. This means there is more uncertainty associated with these values.

*The limit of detection was 2 μg and the limit of quantification was 6.7 μg per sample.

†The disposable 100 cm^2 template could not be used so an estimated 100 cm^2 was sampled.

Table C3. The common fungal species identified in area air samples collected on Side A and Side B of the facility

Species	All area samples		Side A		Side B	
	# Clones	% Total fungi	# Clones	% Total fungi	# Clones	% Total fungi
Golovinomyces spadiceus	41	18.98	38	22.49	3	6.38
Rhodotorula spp.	27	12.50	24	14.20	3	6.38
Penicillium spp.	22	10.19	18	10.65	4	8.51
Cladosporium spp.	14	6.48	8	4.73	6	12.77

Table C4. Detection of fungal clones and *Golovinomyces spadiceus* in various areas of the facility

Area sample	Sample size	Total fungal clones (range)*	*Golovinomyces spadiceus*	
			# Clones (range)*	% Total fungi (range)*
Side A				
Trim room table	2	38.5 (38–39)	19 (17–21)	49.4 (43.6–55.3)
Grow area, close to harvest	1	43	0	0
Grow area, away from harvest	3	11.3 (9–14)	0	0
Harvest check table	1	15	0	0
Side B				
Trim room table, weighing product	1	17	3	17.6
Grow area, near repotting	1	8	0	0
Grow area, away from repotting	4	5 (0–8)	0	0
Dry/cure room	1	2	0	0

*Averages (range) are presented for those areas where multiple air samples were collected.

Table C5. Particle monitoring results for three locations (mg/m^3)

Location	Particle size				
	PM_1	$PM_{2.5}$	Respirable	PM_{10}	Total
Side A - Harvest					
Average	0.026	0.027	0.028	0.039	0.061
Minimum	0.012	0.13	0.014	0.016	0.018
Maximum	0.12	0.12	0.15	0.31	0.61
Side A - Trim room					
Average	0.025	0.025	0.027	0.038	0.064
Minimum	0.14	0.014	0.015	0.016	0.016
Maximum	0.12	0.12	0.13	0.22	0.54
Side B - Trim room					
Average	0.03	0.03	0.032	0.043	0.077
Minimum	0.011	0.012	0.012	0.014	0.018
Maximum	0.1	0.11	0.11	0.21	0.53

Table C6. Symptoms believed to be work-related reported by employees over the last 4 weeks

Symptom	Cultivation/harvesting employees (n = 25) Frequency (%)	Trimming employees (n = 25) Frequency (%)
Stuffy nose or sinus problems	10 (40)	18 (72)
Runny nose	9 (36)	12 (48)
Back pain	9 (36)	15 (60)
Rash on skin	7 (28)	8 (32)
Red or irritated eyes	6 (24)	9 (36)
Difficulty hearing	6 (24)	6 (25)*
Fatigue	5 (20)	7 (28)
Hand or wrist pain	5 (20)	11 (44)
Hives	5 (20)	2 (8)
Shoulder pain	5 (20)	8 (32)
Leg pain	4 (16)	4 (16)
Foot pain	4 (16)	4 (16)
Lightheadedness	4 (16)	9 (36)
Respiratory problems	4 (16)	8 (32)
Anxiety	3 (12)	8 (32)
Chest tightness	3 (12)	3 (13)*
Shortness of breath	3 (12)	3 (12)
Headaches	3 (12)	13 (52)
Changes in appetite	1 (4)	1 (4)
Sore throat	1 (4)	7 (28)
Frequent changes in mood	1 (4)	2 (8)*
Difficulty concentrating	0 (0)	2 (8)
Depression	0 (0)	4 (16)
Difficulty sleeping	0 (0)	3 (12)
Unexplained fevers	0 (0)	0 (0)

*N = 24 (due to lack of response)

Table C7. Frequency of affirmative responses to physical working conditions items during confidential medical interviews

Working conditions items	Cultivation/harvesting employees (n = 25) Frequency (%)	Trimming employees (n = 25) Frequency (%)
During your work, are you made uncomfortable by:		
Bright light	18 (72)	10 (40)
Dust/dirt?	17 (68)	16 (64)
Heat?	12 (48)	7 (28)
Changes in temperature?	9 (36)	8 (32)
Loud noise?	9 (36)	13 (52)
Bending down regularly?	9 (36)	5 (20)
Stagnant water?	9 (36)	4 (16)
Dry air?	9 (36)	10 (40)
Damp air?	8 (32)	2 (8)
Lack of fresh air?	8 (32)	15 (60)
Lengthy periods of being in the same physical position?	7 (28)	14 (56)
Lengthy periods of performing repetitive motions?	6 (24)	10 (40)
Pests?	6 (24)	9 (36)
Lengthy standing?	5 (20)	9 (36)
Lifting/carrying items?	4 (16)	2 (8)
Bad smells/odors?	3 (12)	13 (52)
Lengthy sitting?	1 (4)	9 (36)
Reaching up regularly	1 (4)*	2 (8)
Cold	1 (4)	10 (40)

*N = 24 (due to lack of response)

Table C8. Employee responses to psychosocial items during confidential medical interviews

Psychosocial item	Cultivation/harvesting employees (n = 25) frequency of “yes” responses (%)	Trimming employees (n = 25) frequency of “yes” responses (%)
Do your supervisors listen to what you have to say?	25 (100)	19 (76)
Do you need to spend a lot of time being alert at work?	24 (96)	14 (56)
Do you feel free to report health or safety concerns at work?	24 (96)	19 (76)
Can you take a break if you need to?	24 (96)	18 (72)
Is it clear to you what your responsibilities are at work?	24 (96)	24 (96)
Do you normally enjoy your work?	24 (96)	24 (96)
Do you have enough variation in your work?	24 (96)	16 (64)
Do you believe you were trained well for your job?	24 (96)	16 (64)
Are you well-informed about the goals and results of your work?	23 (92)	20 (80)
Does your employer encourage you to stay home if you are ill?	22 (88)	23 (92)
Can you usually manage to take a day off easily?	21 (88)*	21 (84)
Is your work usually well organized?	21 (84)	14 (56)
Is your work highly physical?	20 (80)	3 (12)
Is your work made more difficult due to other people not doing their job properly?†	19 (79)*	19 (76)
Does this work offer you sufficient job security?	19 (79)*	17 (71)*
Do you always have the tools necessary to complete your work?	19 (76)	20 (80)
Do you trust your employer to look out for your well-being?	19 (76)	19 (76)
Does your work require a lot of thinking?	15 (60)	2 (8)
Do you regularly work under short deadlines?†	12 (48)	8 (32)
Is your work made more difficult due to other people being absent?†	9 (36)	8 (32)
Do you have a lot of say or get to make many decisions as part of your job?	9 (36)	8 (32)
Do you often have to do something which isn’t part of your job description?†	5 (20)	10 (40)
Does your work interfere with your private or family life?†	4 (16)	1 (4)
Do you have poor relations with any of your coworkers?†	1 (4)	2 (8)
Do you have poor relations with any of your supervisors?†	0 (0)	4 (16)

*N = 24 (due to lack of response)

†Item has negative connotation

Section D: Occupational Exposure Limits

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 preexisting 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 time-weighted average (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 short-term exposure limits (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.

- OSHA, an agency of the U.S. Department of Labor, publishes PELs [29 CFR 1910 for general industry; 29 CFR 1926 for construction industry; and 29 CFR 1917 for maritime industry]. These legal 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 2007]. 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 include the threshold limit values or TLVs, which are recommended by the American Conference of Governmental Industrial Hygienists (ACGIH®). The ACGIH 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 2021].

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 https://www.dguv.de/ifa/gestis/gestis-stoffdatenbank/index-2.jsp, contains international limits for more than 2,000 hazardous substances and is updated periodically.

OSHA (Public Law 91-596) 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. 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.

Endotoxin

Endotoxins are found throughout the agricultural environment. Endotoxins are located in the cell wall of Gram-negative bacteria and are released when the bacterial cell is lysed (broken down) or when it is multiplying. In experimental studies, human volunteers exposed via inhalation to high levels of endotoxin experienced airway and alveolar inflammation as well as chest tightness, fever, and malaise, and have an acute reduction in lung function, as measured by the forced expiratory volume in one second [Castellan 1995]. Airborne endotoxin exposures between 45 and 400 EU/m^3 have been associated with acute airflow obstruction, mucous membrane irritation, chest tightness, cough, shortness of breath, fever, and wheezing [Thorne and Duchaine 2007]. Chronic health effects that have been associated with airborne endotoxin exposures include asthma, chronic bronchitis, bronchial hyperreactivity, chronic airway obstruction, hypersensitivity pneumonitis, and organic dust toxic syndrome [Duquenne et al. 2013; Rylander 2006]. Some studies suggest that high environmental and occupational endotoxin exposures may protect exposed individuals from developing atopic sensitization [Rylander 2006]. Rylander and Jacobs [1997] have suggested an occupational threshold concentration for endotoxin equivalent to 100 EU/m^3 of air to prevent airway inflammation.

No accepted OELs for endotoxins have been developed in the United States because of the variability of sampling and analytical methods, and because of a lack of data showing a consistent dose-response relationship [AIHA 2005; Duquenne et al. 2013]. In 2010, DECOS recommended a health-based OEL for airborne endotoxin of 90 EU/m^3 as an 8-hour TWA [DECOS 2010].

Δ9-THC

Δ9-THC is the psychoactive component of cannabis. There is no OEL for Δ9-THC. Occupational exposures to cannabinoids are thought to be mostly through skin absorption and ingestion. The long-term health effects of these occupational exposure routes are currently unknown. Past Δ9-THC and health effects research has focused primarily on inhalation in nonoccupational settings. Short term effects may include cannabis intoxication, which is characterized by symptoms such as impaired motor coordination, euphoria, anxiety, sensation of slowed time, impaired judgement, social withdrawal

[American Psychiatric Association 2013]. These symptoms occur during or within 2 hours of cannabis use [American Psychiatric Association 2013]. The National Institute on Drug Abuse [2016] also characterizes mood changes, diminished memory, and disorientation as short-term health effects of an effective dose of cannabis. Some studies have associated chronic exposure to firsthand cannabis smoke with social anxiety disorder, depressive disorders, psychosis, and respiratory symptoms [National Academies of Sciences, Engineering, and Medicine 2017].

The adverse health effects associated with nonmedicinal and chronic consumption of Δ9-THC derived from *C. sativa* and *Cannabis indica* have been extensively studied and reviewed [Hall and Degenhardt 2014; Volkow et al. 2014]. In contrast, the short-term and long-term health effects of occupational exposure to Cannabis species material are not well described in the literature.

Δ9-THCA, CBD, and CBN

Δ9-THCA, CBD, and CBN are several other of more than 60 cannabinoids found in small quantities in cannabis. These are not psychoactive substances, meaning they do not change a person's mental state by affecting the way the brain and nervous system work. Unlike Δ9-THC, these cannabinoids do not cause intoxication or a "high." There are currently no OELs for Δ9-THCA, CBD, or CBN.

Hemp

Hemp, also derived from *Cannabis sativa*, is used for a variety of purposes including fiber, rope, paper composites, food, and oil and oil-based products [United States Department of Agriculture 2000]. Occupational hemp exposure can result in a variety of clinical symptoms including sinusitis, byssinosis, and reductions in lung function [Zuskin et al. 1990; Zuskin et al. 1992; Zuskin et al. 1994]. Employees who directly handle the plant are particularly at risk [Barbero and Flores 1967; Valić et al. 1968; Zuskin et al. 1990; Zuskin et al. 1994]. There is no OEL for hemp. Transdermal applications of medicinal cannabis demonstrate that occupational dermal absorption is a potential exposure route [Goldsmith et al. 2015]. Other studies have demonstrated dermal reactions such as an urticarial rash (hives) in subjects who directly contact cannabis [Basharat et al. 2011; Ozyurt et al. 2014]. Urticaria has also occurred in forensic specialists and law enforcement officers following the handling of cannabis [Herzinger et al. 2011; Majmudar et al. 2006; Mayoral et al. 2008; Williams et al. 2008]. Several of these plant components have recently been shown to produce high molecular weight proteins that can result in the allergic sensitization following personal exposure [Nayak et al. 2013].

Ozone

Ozone is a colorless to blue gas with a pungent odor. Exposure to ozone may cause headaches, coughing, dry throat, shortness of breath, a heavy feeling in chest, and fluid in the lungs. Higher levels of exposure can lead to more severe symptoms. Chronic exposure may lead to asthma. Workers may be harmed from exposure to ozone. The level of exposure depends upon the dose, duration, and work being done [NIOSH 2019]. The NIOSH REL for ozone is 0.1 ppm and is to be evaluated as a ceiling limit, and the current OSHA PEL for ozone is 0.1 ppm [NIOSH 2007]. The current ACGIH TLV is based on the amount of physical exertion or work load required for the job and is to be averaged over an 8–hour period. The TLV is 0.1 ppm for jobs requiring light physical exertion, 0.08 ppm for moderate physical exertion, 0.05 ppm for heavy physical exertion. A separate TLV for ozone is 0.2 ppm for heavy, moderate, or light work loads less than or equal to 2 hours in duration [ACGIH 2021].

Noise

Noise-induced heating loss (NIHL) is an irreversible condition that progresses with noise exposure. It is caused by damage to the nerve cells of the inner ear and, unlike some other types of hearing disorders, cannot be treated medically [Berger et al. 2003]. More than 22 million U.S. workers are estimated to be exposed to workplace noise levels above 85 dBA [Tak et al. 2009]. NIOSH estimates that workers exposed to an average daily noise level of 85 dBA over a 40-year working lifetime have an 8% excess risk of material hearing impairment. This excess risk increases to 25% for an average daily noise exposure of 90 dBA [NIOSH 1998]. NIOSH defines material hearing impairment as an average of the hearing threshold levels for both ears that exceeds 25 dB at frequencies of 1,000 Hz; 2,000 Hz; 3,000 Hz; and 4,000 Hz.

Although hearing ability commonly declines with age, exposure to excessive noise can increase the rate of hearing loss. In most cases, NIHL develops slowly from repeated exposure to noise over time, but the progression of hearing loss is typically the greatest during the first several years of noise exposure. NIHL can also result from short-duration exposures to high noise levels or even from a single exposure to an impulse noise or a continuous noise, depending on the intensity of the noise and the individual's susceptibility to NIHL [Berger et al. 2003]. Noise-exposed workers can develop substantial NIHL before it is clearly recognized. Even mild hearing losses can impair a person's ability to understand speech and hear many important sounds. In addition, some people with NIHL also develop tinnitus. Tinnitus is a condition in which a person perceives sound in one or both ears, but no external sound is present. Persons with tinnitus often describe hearing ringing, hissing, buzzing, whistling, clicking, or chirping like crickets. Tinnitus can be intermittent or continuous and the perceived volume can range from soft to loud. Currently, there is no cure for tinnitus.

The preferred unit for reporting noise measurements is dBA. A-weighting is used because it approximates the "equal loudness perception characteristics of human hearing for pure tones relative to a reference of 40 dB at a frequency of 1,000 Hz" and is considered to provide a better estimation of hearing loss risk than using unweighted or other weighting measurements [Berger et al. 2003].

Employees exposed to noise should have baseline and yearly hearing tests to evaluate their hearing thresholds and determine whether their hearing has changed over time. Hearing testing should be done in a quiet location, such as an audiometric test booth, where background noise does not interfere with accurate measurement of hearing thresholds. In workplace hearing conservation programs, hearing thresholds must be measured at 500 Hz; 1,000 Hz; 2,000 Hz; 3,000 Hz; 4,000 Hz; and 6,000 Hz. Additionally, NIOSH recommends testing at 8,000 Hz [NIOSH 1998].

The OSHA hearing conservation standard requires analysis of changes from baseline hearing thresholds to determine if the changes are substantial enough to meet OSHA criteria for a standard threshold shift (STS). OSHA defines an STS as a change in hearing threshold (relative to the baseline hearing test) of an average of 10 dB or more at 2,000 Hz; 3,000 Hz; and 4,000 Hz in either ear [29 CFR 1910.95]. If an STS occurs, the company must determine if the hearing loss also meets the requirements to be recorded on the OSHA Form 300 Log of Work-Related Injuries and Illnesses [29 CFR 1904.1]. In contrast to OSHA, NIOSH defines an STS as a change in the hearing threshold level of 15 dB or more (relative to the baseline hearing test) at any test frequency in either ear measured twice in succession [NIOSH 1998].

The NIOSH REL for noise is 85 dBA as an 8-hour TWA. For calculating exposure limits, NIOSH uses a 3-dB time/intensity trading relationship, or exchange rate. Using the NIOSH criterion, an employee can be exposed to 88 dBA for no more than 4 hours, 91 dBA for 2 hours, 94 dBA for 1 hour, 97 dBA for 0.5 hours, etc. Exposure to impulsive noise should never exceed 140 dBA. For extended work shifts, NIOSH adjusts the REL to 84.5 dBA for a 9-hour shift, 84.0 dBA for a 10-hour shift, 83.6 dBA for an 11-hour shift, and 83.2 dBA for a 12-hour work shift. NIOSH recommends the use of hearing protection and the implementation of a hearing loss prevention program when noise exposures exceed the REL [NIOSH 1998].

The OSHA noise standard specifies a PEL of 90 dBA and an AL of 85 dBA, both as 8-hour TWAs. OSHA uses a less conservative 5-dB exchange rate for calculating the PEL and AL. Using the OSHA criterion, an employee may be exposed to noise levels of 95 dBA for no more than 4 hours, 100 dBA for 2 hours, 105 dBA for 1 hour, 110 dBA for 0.5 hours, etc. Exposure to impulsive or impact noise must not exceed 140 dB peak noise level. OSHA does not adjust the PEL for extended work shifts. However, the AL is adjusted to 84.1 dBA for a 9-hour shift, 83.4 dBA for a 10-hour shift, 82.7 dBA for an 11-hour shift, and 82.1 dBA for a 12-hour work shift. OSHA requires implementation of a hearing conservation program when noise exposures exceed the AL [29 CFR 1910.95].

Section E: References

Background

Barcott B, Whitney B, Bailey J [2021]. Leafly Jobs Report 2021. Seattle, WA: Leafly Holdings, Inc., https://leafly-cms-production.imgix.net/wp-content/uploads/2021/02/13180206/Leafly-JobsReport-2021-v14.pdf.

NIOSH [2017]. Evaluation of potential hazards during harvesting and processing cannabis at an outdoor organic farm. By Couch J, Victory K, Lowe B, Burton N, Green B, Nayak A, Lemons A, Beezhold D. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2015-0111-3271, http://www.cdc.gov/niosh/hhe/reports/pdfs/2015-0111-3271.pdf.

NIOSH [2019]. Evaluation of a medicinal cannabis manufacturing facility with an indoor and outdoor grow operation. By Couch J, Wiegand D, Grimes GR, Green BJ, Lemons AR, Glassford E, Zwack L, Jackson SR, Beezhold D. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2016-0090-3317, https://www.cdc.gov/niosh/hhe/reports/pdfs/2016-0090-3317revised082019.pdf.

Confidential Medical Interviews

Clark MM, Warren BA, Hagen PT, Johnson BD, Jenkins SM, Werneburg BL, Olsen KD [2011]. Stress level, health behaviors, and quality of life in employees joining a wellness center. Am J Health Promot *26*(1):21–25, http://doi.org/10.4278/ajhp.090821-QUAN-272.

Weel ANH, Fortuin RJ [1998]. Design and trial of a new questionnaire for occupational health surveys in companies. Occup Med *48*(8):511–518, https://doi.org/10.1093/occmed/48.8.511.

Discussion

Dugan FM [2013]. *Golovinomyces spadiceus* causing powdery mildew on *Coreopsis* hybrid 'Full Moon' (Heliantheae, Asteraceae) in Washington State. N Am Fungi *8*:1–3, https://doi.org/10.2509/naf2013.008.001.

Dutkiewicz J, Krysińska-Traczyk E, Skórska C, Sitkowska J, Prazmo Z, Golec M [2001]. Exposure to airborne microorganisms and endotoxin in herb processing plants. Ann Agric Environ Med *8*(2):201–211.

Félix-Gastélum R, Olivas-Peraza DD, Quiroz-Figueroa FR, Leyva-Madrigal KY, Peñuelas-Rubio O, Espinosa-Matías S, Maldonado-Mendoza IE [2019]. Powdery mildew caused by *Golovinomyces spadiceus* on wild sunflower in Sinaloa, Mexico. Can J Plant Pathol *41*(2):301–309, https://doi.org/10.1080/07060661.2019.1577916.

Fishwick D, Allan LJ, Wright A, Curran AD [2001]. Assessment of exposure to organic dust in a hemp processing plant. Ann Occup Hyg *45*(7):577–583, http://doi.org/10.1093/annhyg/45.7.577.

Green BJ, Couch J, Lemons AR, Burton N, Victory KR, Nayak AP, Beezhold DH [2018]. Microbial hazards during harvesting and processing at an outdoor United States cannabis farm. J Occup Environ Hyg *15*(5):430–440, https://doi.org/10.1080/15459624.2018.1432863.

Moparthi S, Bradshaw M, Frost K, Hamm PB, Buck JW [2018]. First report of powdery mildew caused by *Golovinomyces spadiceus* on okra in the United States. Plant Dis *102*(8):1664, https://doi.org/10.1094/PDIS-01-18-0179-PDN.

NIOSH [2017]. Evaluation of potential hazards during harvesting and processing cannabis at an outdoor organic farm. By Couch J, Victory K, Lowe B, Burton N, Green B, Nayak A, Lemons A, Beezhold D. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2015-0111-3271, http://www.cdc.gov/niosh/hhe/reports/pdfs/2015-0111-3271.pdf.

Pépin N, Punja ZK, Joly DL [2018]. Occurrence of powdery mildew caused by *Golovinomyces cichoracearum sensu lato* on *Cannabis sativa* in Canada. Plant Disease *102*(12):2664, https://doi.org/10.1094/PDIS-04-18-0586-PDN.

Punja ZK, Collyer D, Scott C, Lung S, Holmes J, Sutton D [2019]. Pathogens and molds affecting production and quality of *Cannabis sativa* L. Front Plant Sci *10*(1120):1–23, https://doi.org/10.3389/fpls.2019.01120.

Skórska C, Sitkowska J, Krysińska-Traczyk E, Cholewa G, Dutkiewicz J [2005]. Exposure to airborne microorganisms, dust and endotoxin during processing of peppermint and chamomile herbs on farms. Ann Agric Environ Med *12*(2):281–288.

Szarka D, Tymon L, Amsden B, Dixon E, Judy J, Gauthier N [2019]. First report of powdery mildew caused by *Golovinomyces spadiceus* on industrial hemp (*Cannabis sativa*) in Kentucky. Plant Dis *103*(7):1773, https://doi.org/10.1094/PDIS-01-19-0049-PDN.

Thilsing T, Madsen AM, Basinas I, Schlünssen V, Tendal K, Bælum J [2015]. Dust, endotoxin, fungi, and bacteria exposure as determined by work task, season, and type of plant in a flower greenhouse. Ann Occup Hyg *59*(2):142–157, http://doi.org/10.1093/annhyg/meu090.

Trigiano RN, Boggess SL, Bernard EC [2017]. First report of powdery mildew caused by *Golovinomyces spadiceus* on green and gold (*Chrysogonum virginianum*) in the United States. Plant Dis *102*(1):252, https://doi.org/10.1094/PDIS-08-17-1292-PDN.

Exposure Assessment

Ambach L, Penitschka F, Broillet A, Konig S, Weinmann W, Bernhard W [2014]. Simultaneous quantification of delta-9-THC, THC-acid A, CBN, and CBD in seized drugs using HPLC-DAD. Forensic Sci Int *243*(Suppl C):107–111, https://doi.org/10.1016/j.forsciint.2014.06.008.

DECOS [2010]. Endotoxins: health-based recommended occupational exposure limit. The Hague, Netherlands: Health Council of The Netherlands, Dutch Expert Committee on Occupational Standards, Publication no. 2010/04OSH, https://www.healthcouncil.nl/documents/advisory-reports/2010/07/15/endotoxins-health-based-recommended-occupational-exposure-limit.

Green BJ, Lemons AR, Park Y, Cox-Ganser JM, Park JH [2017]. Assessment of fungal diversity in a water-damaged office building. J Occup Environ Hyg *14*(4):285–293, https://doi.org/10.1080/15459624.2016.1252044.

Green BJ, Couch J, Lemons AR, Burton N, Victory KR, Nayak AP, Beezhold DH [2018]. Microbial hazards during harvesting and processing at an organic U.S. cannabis farm. J Occup Environ Hyg *15*(5):430–440, https://doi.org/10.1080/15459624.2018.1432863.

Noise

Berger EH, Royster LH, Royster JD, Driscoll DP, Layne M, eds. [2003]. The noise manual. 5th rev. ed. Fairfax, VA: American Industrial Hygiene Association.

NIOSH [1998]. Criteria for a recommended standard: occupational noise exposure (revised criteria 1998). 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. 98-126, http://www.cdc.gov/niosh/docs/98-126/pdfs/98-126.pdf.

Tak S, Davis RR, Calvert GM [2009]. Exposure to hazardous workplace noise and use of hearing protection devices among U.S. workers—NHANES, 1999–2004. Am J Ind Med *52*(5):358–371, http://doi.org/10.1002/ajim.20690.

Occupational Exposure Limits

ACGIH [2021]. 2021 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

AIHA [2005]. Field guide for the determination of biological contaminants in environmental samples. 2nd ed. Falls Church, Virginia: American Industrial Hygiene Association.

American Psychiatric Association [2013]. Diagnostic and statistical manual of mental disorders. 5th ed. Arlington, VA: American Psychiatric Association.

Barbero A, Flores R [1967]. Dust disease in hemp workers. Arch Environ Health *14*(4):529–532, https://doi.org/10.1080/00039896.1967.10664789.

Basharat P, Sussman G, Beezhold D, Leader N [2011]. Hypersensitivity reactions to marijuana. J Allergy Clin Immunol *127*(2):AB178, http://doi.org/10.1016/j.jaci.2010.12.707.

Castellan RM [1995]. Respiratory health effects of inhaled endotoxins: byssinosis and beyond. In: McDuffie H, Dosman J, Semchuk K, Olenchock S, eds. Agricultural health and safety—workplace, environment, sustainability. Boca Raton, FL: CRC Press, pp. 97–100.

CFR [2021]. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

DECOS [2010]. Endotoxins: health-based recommended occupational exposure limit. The Hague, Netherlands: Health Council of The Netherlands, Dutch Expert Committee on Occupational Standards, Publication no. 2010/04OSH, https://www.healthcouncil.nl/documents/advisory-reports/2010/07/15/endotoxins-health-based-recommended-occupational-exposure-limit.

Duquenne P, Marchand G, Duchaine C [2013]. Measurement of endotoxins in bioaerosols at workplace: a critical review of literature and a standardization issue. Ann Occup Hyg *57*(2):137–172, http://doi.org/10.1093/annhyg/mes051.

Goldsmith RS, Targino MC, Fanciullo GJ, Martin DW, Hartenbaum NP, White JM, Franklin P [2015]. Medical marijuana in the workplace: challenges and management options for occupational physicians. J Occup Environ Med *57*(5):518–525, http://doi.org/10.1097/JOM.0000000000000454.

Hall W, Degenhardt L [2014]. The adverse health effects of chronic cannabis use. Drug Test Anal *6*(1–2):39–45, http://doi.org/10.1002/dta.1506.

Herzinger T, Schöpf P, Przybilla B, Ruëff F [2011]. IgE-mediated hypersensitivity reactions to cannabis in laboratory personnel. Int Arch Allergy Immunol *156*(4):423–426, http://doi.org/10.1159/000324444.

Majmudar V, Azam NA, Finch T [2006]. Contact urticaria to *Cannabis sativa*. Contact Dermatitis *54*(2):127, http://doi.org/10.1111/j.0105-1873.2006.0560h.x.

Mayoral M, Calderón H, Cano R, Lombardero M [2008]. Allergic rhinoconjunctivitis caused by Cannabis sativa pollen. J Investig Allergol Clin Immunol *18*(1):73–74.

National Academies of Sciences, Engineering, and Medicine [2017]. The health effects of cannabis and cannabinoids: the current state of evidence and recommendations for research. Washington, DC: The National Academies Press; https://dx.doi.org/10.17226/24625.

National Institute on Drug Abuse [2016]. DrugFacts: marijuana. Rockville, MD: U.S. Department of Health and Human Services, National Institutes of Health, National Institute on Drug Abuse, https://www.drugabuse.gov/publications/drugfacts/marijuana.

Nayak AP, Green BJ, Sussman G, Berlin N, Lata H, Chandra S, ElSohly MA, Hettick JM, Beezhold DH [2013]. Characterization of *Cannabis sativa* allergens. Ann Allergy Asthma Immunol *111*(1):32–37e4, http://doi.org/10.1016/j.anai.2013.04.018.

NIOSH [2007]. 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. 2005-149, http://www.cdc.gov/niosh/npg/.

NIOSH [2019]. Ozone. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, https://www.cdc.gov/niosh/topics/ozone.

Ozyurt S, Muderrisoglu F, Ermete M, Afsar F [2014]. Cannabis-induced erythema multiforme-like recurrent drug eruption. Int J Dermatol *53*(1):e22–e23, http://doi.org/10.1111/j.1365-4632.2011.05318.x.

Rylander R [2006]. Endotoxin and occupational airway disease. Curr Opin Allergy Clin Immunol *6*(1):62–66, http://doi.org/10.1097/01.all.0000202356.83509.f7.

Rylander R, Jacobs RR [1997]. Endotoxin in the environment: a criteria document. Int J Occup Environ Health *3*(1):S1–S48.

Thorne PS, Duchaine C [2007]. Airborne bacteria and endotoxin. In: Hurst CJ, Crawford RL, Garland JL, Lipson DA, Mills AL, Stetzenbach LD, eds. Manual of environmental microbiology. 3rd ed. Washington, DC: American Society for Microbiology Press, pp. 989–1004.

United States Department of Agriculture [2000]. Industrial hemp in the United States: status and market potential. United States Drug Administration, Economic Research Service, https://www.ers.usda.gov/publications/pub-details/?pubid=41757.

Valić F, Žuškin E, Walford J, Keršić W, Pauković R [1968]. Bysinnosis, chronic bronchitis, and ventilatory capacities in workers exposed to soft hemp dust. Br J Ind Med *25*(3):176–186, https://doi.org/10.1136/oem.25.3.176.

Volkow ND, Baler RD, Compton WM, Weiss SR [2014]. Adverse health effects of marijuana use. N Engl J Med *370*(23):2219–2227, http://doi.org/10.1056/NEJMra1402309.

Williams C, Thompstone J, Wilkinson M [2008]. Work-related contact urticaria to *Cannabis sativa*. Contact Dermatitis *58*(1):62–63, http://doi.org/10.1111/j.1600-0536.2007.01169.x.

Zuskin E, Kanceljak B, Pokrajac D, Schachter EN, Witek TJ Jr. [1990]. Respiratory symptoms and lung function in hemp workers. Br J Ind Med *47*(9):627–632, https://doi.org/10.1136/oem.47.9.627.

Zuskin E, Kanceljak B, Schachter EN, Witek TJ, Maayani S, Goswami S, Marom Z, Rienzi N [1992]. Immunological findings in hemp workers. Environ Res *59*(2):350–361, https://doi.org/10.1016/s0013-9351(05)80041-6.

Zuskin E, Mustajbegovic J, Schachter EN [1994]. Follow-up study of respiratory function in hemp workers. Am J Ind Med *26*(1):103–115, https://doi.org/10.1002/ajim.4700260109.

Promoting productive workplaces through safety and health research

HHE Report No. 2019-0152-3381