HealthHazard® Evaluation Program

Evaluation of Exposures and Health Concerns at a Coffee Roasting and Packaging Facility

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The Health Hazard Evaluation Program investigates possible health hazards in the workplace under the authority of the Occupational Safety and Health Act of 1970 [29 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].

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Introduction

Request

The National Institute for Occupational Safety and Health (NIOSH) received a management request for a health hazard evaluation at a coffee roasting and packaging facility. The request stated concerns regarding potential employee exposure to diacetyl, 2,3-pentanedione, other volatile organic compounds (VOCs), carbon monoxide (CO), and carbon dioxide (CO_2) during coffee roasting, grinding, and packaging. A new 45 pound (lb) grinder had been added to production, and management was concerned about the larger grinder's impact on air levels of diacetyl, 2,3-pentanedione, VOCs, CO, and CO_2 since a previous health hazard evaluation was performed in 2016.

Workplace

The coffee roasting and packaging facility produced whole bean and ground coffee and had an attached café onsite. The facility employed approximately 21 employees with approximately nine of those employees working in production. Five employees worked in the attached, onsite café. Another retail business was located in the same building next to the coffee roasting and packaging facility.

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

Our Approach

In July 2023, we conducted a site visit to assess exposures to diacetyl, 2,3-pentanedione, CO, CO_2, and total VOC during coffee roasting and packaging, install a ventilated enclosure around the large grinder, assess exposures after installing and operating the ventilated enclosure, and informally interview employees. We completed the following activities during our evaluation:

- Collected full-shift personal and area air samples of diacetyl and 2,3-pentanedione.
- Collected task-based personal and/or area air samples for diacetyl, 2,3-pentanedione, and CO.
- Collected real-time area air samples for CO, CO_2, and total VOCs.
- Built a ventilated enclosure around the large grinder to capture diacetyl, 2,3-pentanedione, and CO emissions from grinding roasted coffee at the large grinder.
- Assessed the efficiency of the ventilated enclosure around the large grinder.
- Informally interviewed employees to learn about their work history, tasks performed, and any health concerns.

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

Our Key Findings

Most personal air samples collected on production employees were above the NIOSH recommended exposure limit (REL) for diacetyl of 5 parts per billion (ppb)

- Personal full-shift measurements for diacetyl (n=13) ranged from 1.2 ppb to 12.5 ppb.
- Six out of seven personal full-shift measurements for diacetyl collected on production employees exceeded the NIOSH REL for diacetyl of 5 ppb. The highest measurements were collected on days prior to installing the ventilated enclosure at the large grinder.
- All personal full-shift samples collected on employees working in the administrative and quality control (QC) areas (n=6) were below the NIOSH REL for diacetyl (including one employee who worked in both the production and administrative areas).

The highest area measurements for diacetyl, 2,3-pentanedione, and CO were collected near the small grinder

- Because area air samples are not personal air samples collected directly on an employee, the NIOSH RELs are not directly applicable to the results for exposure monitoring purposes. However, area air samples can highlight areas with higher exposure risk, and the RELs can be used as points of reference.
- Full-shift area diacetyl concentrations measured near the small grinder ranged from 31.6 ppb to 77.3 ppb and exceeded the NIOSH REL of 5 ppb diacetyl.
- Full-shift area 2,3-pentanedione concentrations measured near the small grinder ranged from 22.8 ppb to 50.5 ppb and exceeded the NIOSH REL of 9.3 ppb 2,3-pentanedione.
- Full-shift continuous area air measurements of CO collected every 10 seconds at the small grinder ranged from less than 0.1 ppm to 1,521 ppm. Multiple measurements exceeded the NIOSH ceiling limit for CO of 200 ppm, and a single measurement (1,521 ppm) exceeded the NIOSH immediately dangerous to life and health (IDLH) value for CO of 1,200 ppm (more information below).

Peak measurements of CO collected at the small grinder exceeded the NIOSH ceiling limit for CO of 200 ppm; a single 10 second measurement exceeded the NIOSH IDLH value for CO of 1,200 ppm

- Peak measurements of CO collected while grinding multiple 12 ounce (oz) and 5 lb bags of coffee at the small grinder exceeded the NIOSH ceiling limit for CO on all days of our survey.
- Peak measurements of CO at the small grinder on all days of our survey ranged from 1,041 ppm to 1,521 ppm. A single 10-second measurement of 1,521 ppm on the first day of our survey exceeded the NIOSH IDLH value for CO of 1,200 ppm. The IDLH value of 1,200 ppm is based on studies that suggested a concentration between 1,500 ppm and 2,000 ppm might be a

dangerous concentration after 1 hour. We note that this 10 second exposure above the IDLH was brief; however, this level should not be exceeded at any time.

- As a temporary solution, a small fan was positioned at the small grinder to blow emissions away from the breathing zone of employees performing grinding tasks at the small grinder, and this lowered average area CO levels during grinding tasks at the small grinder by almost five-fold.
- Using the small fan during grinding tasks lowered peak measurements of CO to levels just below the NIOSH ceiling limit. However, this was based on only one 17-minute sampling period at the small grinder (8-minutes with the fan on and 9-minutes with the fan off), and our single test of the fan on versus off might not apply to all times when the small grinder is used. It is possible the NIOSH ceiling limit could still be exceeded during grinding tasks at the small grinder due to other factors, including grinding different roast levels of coffee (i.e., light, medium, or dark roasts) or different total quantities of coffee (i.e., more than the number of 5 lb bags that were ground in the 8 minutes during sampling).

Most personal and area full-shift air samples for diacetyl, 2,3-pentanedione, and CO collected on production employees or in production areas were lower after the ventilated enclosure at the large grinder was installed and operated

- Measured decreases in concentrations of diacetyl, 2,3-pentanedione, and CO after the ventilated enclosure was installed indicate the ventilated enclosure increased the total amount of air exhausted from the production area and contributed to lower levels of personal exposures to diacetyl and 2,3-pentanedione in the production areas. After the ventilated enclosure at the large grinder was installed and operated, the highest personal full-shift measurements were reduced for diacetyl and 2,3-pentandione.
    - Diacetyl for production employees was reduced from 12.5 ppb to 8.2 ppb.
    - Diacetyl for roaster operators was reduced from 10.7 ppb to 8.8 ppb.
    - 2,3-Pentanedione for production were reduced employees from 7.7 ppb to 4.8 ppb.
    - 2,3-Pentanedione for roaster operators was reduced from 7.8 ppb to 5.4 ppb.
- Comparisons of diacetyl and 2,3-pentanedione measurements collected inside the ventilated enclosure around the large grinder with measurements collected outside of the ventilated enclosure during a grinding task indicated the ventilated enclosure reduced diacetyl and 2,3-pentanedione levels measured at the large grinder by almost 16-fold.
- All production area measurements for diacetyl and 2,3-pentanedione, except for measurements at the small grinder, were reduced after the ventilated enclosure at the large grinder was installed. More grinding of roasted coffee was performed at the small grinder on the days after the ventilated enclosure was installed at the large grinder, and the increased amount of ground coffee likely contributed to elevated levels of diacetyl and 2,3-pentanedione at the small grinder on days after the ventilated enclosure at the large grinder was installed and operated.

- The ventilated enclosure resulted in approximately seven to 12-fold lower levels of CO during grinding tasks at the large grinder. Area measurements of CO collected during grinding tasks at the large grinder ranged from 17.8 ppm to 36.1 ppm inside the ventilated enclosure to 2.0 ppm to 2.9 ppm directly outside of the ventilated enclosure.

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.

Potential Benefits of Improving Workplace Health and Safety:

↑ Improved worker health and well-being	↑ Enhanced image and reputation
↑ Better workplace morale	↑ Superior products, processes, and services
↑ Easier employee recruiting and retention	↑ 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 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 potential worker exposure to diacetyl, 2,3-pentanedione, and CO during grinding of roasted coffee at the small grinder.

Why? We observed elevated personal measurements of diacetyl (98.3 ppb) and 2,3-pentanedione (69.7 ppb) during grinding tasks at the small grinder. We also measured full-shift area levels of diacetyl (31.6 ppb–77.3 ppb) and 2,3-pentanedione (22.8 ppb–50.5 ppb) at the small grinder above the NIOSH REL of 5 ppb for diacetyl and 9.3 ppb for 2,3-pentanedione. We note that because area air samples are not personal air samples collected directly on an employee, the NIOSH RELs are not directly applicable to the results for exposure monitoring purposes. However, area air samples can highlight areas with higher exposure risk, and the NIOSH RELs can be used as points of reference. Additionally, full-shift area measurements at the small grinder were the highest diacetyl, 2,3-pentanedione, and CO measurements on all days of sampling. Diacetyl area measurements near the small grinder were 3- to 31-fold higher than other production areas. Similarly, area measurements near the small grinder for 2,3-pentanedione were 3- to 32-fold higher than other production areas. Reducing emissions of diacetyl and 2,3-pentanedione at the small grinder should help lower production employees' personal exposures to diacetyl and 2,3-pentanedione.

We observed levels of CO at the small grinder while employees ground 12oz and 5lb bags of coffee that exceeded the NIOSH ceiling for CO of 200 ppm and a single, brief, 10-second measurement exceeded the NIOSH IDLH value for CO of 1,200. The IDLH value of 1,200 ppm is based on studies that suggested a concentration between 1,500 and 2,000 ppm might be a dangerous concentration after 1 hour of exposure. A 30-minute exposure to 1,200 ppm CO can produce a carboxyhemoglobin level of 10% to 13% which is associated with headaches. Although the CO level that exceeded the IDLH was brief (10 seconds), neither the NIOSH ceiling limit or IDLH value for CO should be exceeded at any time. When a small fan was used during grinding tasks at the small grinder, peak area levels of CO measured at the small grinder were reduced to levels below the NIOSH ceiling limit for CO. When the fan was used during grinding tasks at the small grinder, the highest peak CO area measurement was 191 ppm.

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

Consult with a ventilation engineer to install local exhaust ventilation at the small grinder. Consider relocating the small grinder to an area with little or no bystander foot traffic.

- Local exhaust ventilation should be installed at the small grinder with the help of a ventilation engineer and considerations for what configuration works best for your facility. Local exhaust ventilation examples include, but are not limited to:
    - A ventilated enclosure at the small grinder
    - A downdraft table at the small grinder
    - An exhaust fan located behind the small grinder
- Consider relocating the small grinder to the area near the ventilated and enclosed large grinder where there is less employee foot traffic to minimize potential exposure to employees not directly using the grinder. Additionally, relocating the small grinder to the same exterior wall area near the large grinder might make implementation of ventilation controls easier.

Encourage employees to minimize spending time at or near the small grinder when coffee is being ground.

- Encourage employees to step away from the small grinder while coffee is being ground, whenever possible.
- Consider rotating grinding tasks between production employees and having employees grind smaller batches of ground coffee at a time to minimize individual employee exposure intensity and duration.

Conduct follow-up monitoring for diacetyl and 2,3-pentanedione on employees with duties at the small grinder and employees who work in the area around the small grinder.

- After ventilation controls have been installed at the small grinder, conduct personal air monitoring for diacetyl and 2,3-pentanedione on all employees with primary duties in the production area using OSHA Sampling Method 1012 for diacetyl and OSHA Sampling Method 1016 for 2,3-pentanedione. Because air levels of VOCs like diacetyl and 2,3-pentanedione can fluctuate based on production schedules, we recommend personal air sampling for diacetyl and 2,3-pentanedione over multiple days.

Recommendation 2: Install a CO monitor near the small grinder that can alert employees to elevated CO levels while performing grinding tasks.

Why? We observed levels of CO at the small grinder while employees ground 12 oz and 5 lb bags of coffee that exceeded the NIOSH ceiling limit for CO of 200 ppm and a single 10-second measurement exceeded the NIOSH IDLH value for CO of 1200. The IDLH value of 1,200 ppm is based on studies that suggested a concentration between 1,500 and 2,000 ppm might be a dangerous concentration after 1 hour. A 30-minute exposure to 1,200 ppm CO can produce a carboxyhemoglobin level of 10%-13% which is associated with headaches. Neither the NIOSH ceiling limit or IDLH value for CO should be exceeded at any time.

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

Install a CO monitor near the small grinder to alert employees if CO levels exceed the ceiling limit of 200 ppm.

- If the CO monitor indicates that CO levels have exceeded the NIOSH ceiling limit, employees should stop grinding and move away from the small grinder to an area of fresh air until the CO level drops below 200 ppm.
- If additional local exhaust ventilation is installed at the small grinder as recommended above in Recommendation 1, CO levels during grinding at the small grinder should be

reduced (ideally to levels below the NIOSH ceiling limit). If CO monitoring indicates that CO levels continue to exceed the NIOSH ceiling limit, work with a ventilation engineer to increase local exhaust ventilation at the small grinder.

Recommendation 3: If follow-up personal air monitoring after installing additional ventilation at the small grinder indicates personal exposures to diacetyl or 2,3-pentanedione are above their respective RELs or short-term exposure limits (STELs), respiratory protection should be used by employees performing grinding tasks at the small grinder.

Why? If follow-up air sampling after engineering controls have been installed indicates personal exposures to diacetyl and 2,3-pentanedione are above their respective NIOSH RELs and STELs, we recommend respiratory protection be used during tasks with elevated exposures. If respiratory protection is used, NIOSH Approved® respirators should be fitted with organic vapor cartridges to protect against diacetyl and 2,3-pentanedione, and particulate filters to protect against dust particles. The choice of respirator should be guided by follow-up personal exposure sampling for diacetyl and 2,3-pentanedione.

Personal protective equipment in the form of respiratory protection is considered the least effective means for controlling hazardous respiratory exposures because breakdowns in implementation can result in insufficient protection. Proper use of respirators requires 1) a comprehensive respiratory protection program and a high level of employee and management involvement and commitment to assure the right type of respirator is chosen for each hazard; 2) respirators are fit tested and maintained in good working order, and 3) respirators are worn when needed. Supporting programs such as training, changeout schedules, and medical assessment are necessary. Respirators should not be the sole method for controlling hazardous inhalation exposures. Rather, respirators should be used until effective engineering and administrative controls are in place.

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

Respiratory protection should be selected and guided by follow-up personal exposure sampling.

- Review the NIOSH website on respiratory protection information.
- Respirators have assigned protection factors (APFs). APF refers to the highest level of protection a properly selected respirator can provide; a higher APF indicates a greater level of protection.
    - Air-purifying half-face respirators have an APF of 10, and air-purifying full-face respirators have an APF of 50.
    - Powered-air purifying respirators might be more comfortable for employees than the air-purifying respirators. The powered-air purifying respirators have APFs of

25, 50, or 1,000. The OSHA APFs can be found in Table 1 of [OSHA Respiratory Protection Standard].

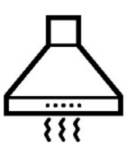
- Respirators should be chosen based on the APF necessary to reduce potential exposures to levels below the NIOSH RELs and STELs for diacetyl and 2,3-pentanedione. There are equations that can be used to determine what APF may be necessary which will then determine the respirator type. You may wish to consult with an Industrial Hygienist or other occupational safety professional for assistance on this.

- If mandatory respiratory protection is used, a written respiratory protection program in compliance with OSHA 29 CFR 1910.134 is required to ensure that (1) employees using such respirators are medically fit to do so, (2) annual fit testing is performed to ensure proper respirator fit, and (3) the respirators are cleaned, stored, and maintained properly.

Recommendation 4: Install permanent local exhaust ventilation at the large grinder.

Why? We installed a temporary ventilated enclosure at the large grinder that lowered levels of diacetyl, 2,3-pentanedione, and CO at the large grinder. Area measurements of diacetyl at the large grinder were reduced to levels below the NIOSH REL after the ventilated enclosure at the large grinder was installed. Measurements of diacetyl and 2,3-pentanedione collected inside the ventilated enclosure and outside of the ventilated enclosure during a grinding task indicated the ventilated enclosure reduced diacetyl and 2,3-pentanedione levels measured at the large grinder by almost 16-fold. The ventilated enclosure resulted in approximate 7- to 12-fold lower levels of CO during grinding tasks at the large grinder. However, the ventilated enclosure we installed at the large grinder was designed to be temporary, and a permanent local exhaust ventilation system, such as a ventilated enclosure, should be installed to replace the temporary ventilated enclosure at the large grinder.

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



Consult with a ventilation engineer to install permanent local exhaust ventilation at the small grinder.

- Local exhaust ventilation should be installed at the small grinder with the help of a ventilation engineer and considerations for what configuration works best for your facility. Local exhaust ventilation examples include, but are not limited to:
  - A ventilated enclosure at the large grinder
  - A downdraft table at the large grinder
  - An exhaust fan located behind the large grinder

Recommendation 5: Ensure employees understand the hazards associated with working in a coffee roasting and packaging facility and how to protect themselves.

Why? OSHA's Hazard Communication Standard, also known as the "Right to Know Law" (29 CFR 19.10.1200), requires that employees are informed and trained on potential work hazards and associated safe practices, procedures, and protective measures.

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

Train employees on potential workplace hazards (e.g., diacetyl, 2,3-pentanedione, CO, and CO_2), what precautions they should take to protect themselves, and workplace policies for reporting their concerns.

Recommendation 6: Encourage employees to report any new, persistent, or worsening respiratory symptoms, particularly those with a work-related pattern, to their healthcare providers and, as instructed by their employer, to a designated individual at their workplace.

Why? Early recognition of work-related respiratory symptoms can help identify potential occupational exposures and risk factors for disease and help prioritize interventions to prevent work-related lung disease in employees. Work-related symptoms are symptoms that typically improve on days away from work or on vacation. Workers should also discuss persistent symptoms that do not resolve, with their healthcare providers. An individualized management plan (such as assigning an affected employee to a different work location, perhaps at home or a remote site) is sometimes required, depending upon medical findings and recommendations of the individual's healthcare provider.

Supporting Technical Information

Evaluation of Exposures and Health Concerns at a Coffee Roasting and Packaging Facility

HHE Report No. 2023-0027-3417

June 2025

Section A: Workplace Information

Employee Information

Number of employees: At the time of our survey, 21 employees worked for the company.

Length of shift: 8 hours to 9.5 hours

History of Issue at Workplace

Request basis: The management request stated concerns regarding potential worker exposure during coffee roasting, grinding, and packaging to diacetyl, 2,3-pentanedione, other volatile organic compounds (VOCs), carbon monoxide (CO), and carbon dioxide (CO_2). The request also shared concerns about a new, larger (45 lb) grinder that had been added to production and the potential for changes in levels of diacetyl, 2,3-pentanedione, VOCs, CO, and CO_2. NOISH performed air sampling during a previous health hazard evaluation in 2016 before the larger grinder was installed.

Previous issues: During the health hazard evaluation in 2016 [NOISH 2017] some personal full-shift exposure measurements to diacetyl and 2,3-pentanedione were above the NIOSH recommended exposure limits (RELs) of 5 parts per billion (ppb) for diacetyl and 9.3 ppb for 2,3-pentanedione. The highest personal full-shift exposure measurements of diacetyl or 2,3-pentanedione during that survey were 18.8 ppb for diacetyl and 18.7 ppb for 2,3-pentanedione which were measured on production employees. No exposure levels in the café, breakroom, or office areas exceeded the RELs for diacetyl or 2,3-pentanedione.

Process Description

At the time of our July 2023 survey, green coffee beans were received in burlap bags and stored in the production space in the green bean storage area. Approximately 16,000 to 20,000 pounds (lbs) of green coffee beans were received each month. One roaster, with a cooling drum and downdraft exhaust system, was used to roast and cool coffee beans for subsequent packaging. The roaster operator scooped green coffee beans into a five-gallon bucket to pre-weigh the green beans prior to adding them to the roaster. Starting roast weights ranged from 15 lbs to 44 lbs, and each roast took approximately 10 minutes to 14 minutes to complete. Once a roast was complete, the roaster operator opened the roaster to allow the roasted beans to enter the downdraft cooling bin where they cooled for 2 minutes to 3 minutes. After cooling, the roasted beans were dispensed into a single storage tote that was covered and allowed to sit in the tote for two to four days prior to (1) packaging (if whole bean coffee) or (2) grinding and packaging (if ground coffee). Coffee was ground using one of two grinders: (1) a large grinder which could grind up to 45 lbs of coffee at a time, or (2) a small grinder which could grind up to 5 lbs of coffee at a time.

Coffee ground at the small grinder was weighed into individual bags (weights included 12 ounce (oz), 1 lb, 3 lb, or 5 lb bags); multiple bags of pre-weighed whole bean coffee were stored in a storage tote at the small grinder for subsequent grinding. Grinding coffee occurred in batches. When grinding coffee, an employee dumped a single bag of whole bean coffee into the small grinder and then placed the bag under the dispenser to directly package the dispensed ground coffee. The employee ground multiple bags from the entire tote, and sometimes would grind coffee from multiple storage totes of coffee.

Coffee to be ground at the large grinder was transferred in its storage tote by an employee to the large grinder. An employee used a small step ladder to carry the tote up to the top of the grinder and then dispense the coffee into the large grinder for grinding. A storage tote with 37 lbs of coffee took approximately 5 minutes to 10 minutes to finish grinding at the large grinder; during this time, the employee performed other tasks.

A weigh-pack machine was used to weigh and package whole bean or ground coffee. The most common weights for packaged coffee were 12 oz, 1 lb, 3 lbs, and 5 lbs. Ground coffee was packaged in batches. An employee cleaned the weigh-pack machine after each batch of ground coffee was packaged. After packaging at the weigh-pack machine, the packaged coffee was stored in the finished goods area for two to seven days prior to being used or sold in the attached onsite café or shipped to offsite locations.

The attached café was located onsite but separated from the production area by a wall and two doors that were kept closed except for when employees needed to enter or exit the production area. The administrative offices and break room were also separated from the production area by a wall and two doors that were kept closed except for when employees needed to enter or exit the production area.

Section B: Methods, Results, and Discussion

Exposure Assessment

Methods: Air sampling for diacetyl and 2,3-pentanedione

We collected personal and area air samples for diacetyl and 2,3-pentanedione on silica gel sorbent tubes during our industrial hygiene survey, over multiple days. The samples were collected and analyzed according to the modified OSHA sampling and analytical Methods 1013 for diacetyl and 1016 for 2,3-pentanedione [LeBouf and Simmons 2017; OSHA 2008, 2010]. In accordance with the two methods, two glass silica gel sorbent tubes were connected by a piece of tubing and inserted into a protective, light-blocking cover. The tubes were connected in series to a sampling pump pulling air through the tubes at a flow rate of 50 milliliters per minute (mL/min). The sampling setup was attached to an employee's breathing zone or placed in an area basket in various places throughout the facility. For full-shift sampling, we collected two consecutive 3-hour samples and calculated the time-weighted average (TWA) concentration from the two samples, assuming the total 6-hour monitoring results reflected a full work shift (8-hour) TWA exposure. Although this might introduce some error, it is a conservative approach more protective of employees than the alternative assumption of no exposure during the last two hours of the shift. We refer to these samples as "full-shift samples" throughout this report. We also collected personal short-term task-based samples in the same manner, but the sampling pump flow rate was 200 mL/min as detailed in OSHA Methods 1013 and 1016 [OSHA 2008, 2010]. Sampling times were dependent on the duration of the task being performed.

Analyses of samples were performed by a Bureau Veritas North America laboratory. The limit of detections (LOD) for diacetyl and 2,3-pentanedione sampling results were the lowest mass that the instruments could detect above background and was a criterion used to determine whether to report a result from a sample. The LODs were 0.02 micrograms per sample (μg/sample) for diacetyl and 0.02 μg/sample for 2,3-pentanedione. These equate to 0.3 ppb for diacetyl and 0.27 ppb for 2,3-pentanedione, for a 6-hour full-shift air sample but vary depending on the volume of air collected during the sampling period.

Results: Air sampling for diacetyl and 2,3-pentanedione

We use mandatory (legally enforceable) and recommended occupational exposure limits (OELs) when evaluating workplace hazards. OELs for diacetyl and 2,3-pentanedione can be seen in Table D1.

Full-shift personal air sampling for diacetyl and 2,3-pentanedione

Full-shift personal air sampling results for diacetyl and 2,3-pentanedione can be seen in Table C1. We collected 13 full-shift personal samples on administrative and production employees. Full-shift personal measurements for diacetyl ranged from 1.2 ppb to 12.5 ppb and 2,3-pentanedione ranged from 0.9 ppb to 7.8 ppb. Six out of seven personal measurements for diacetyl collected on employees working in the production area exceeded the NIOSH REL for diacetyl of 5 ppb [NOISH 2016]. The highest measurements (range: 5.2 ppb to 12.5 ppb) were collected on the two days prior to installing the ventilated enclosure at the large grinder. All personal samples collected on employees working in the administrative and QC areas (n=6) were below the NIOSH REL for diacetyl of 5 ppb (including one employee who worked in both production and administrative areas). All personal measurements for 2,3-pentanedione were below the NIOSH REL for 2,3-pentanedione of 9.3 ppb. All personal air samples had detectable levels of diacetyl and 2,3-pentanedione; no samples were below the limit of detections for diacetyl and 2,3-pentanedione.

Full-shift area air sampling for diacetyl and 2,3-pentanedione

Because area air samples are not personal air samples collected directly on an employee, the NIOSH RELs are not directly applicable to the results for exposure monitoring purposes. However, area air samples can highlight areas with higher exposure risk, and the OELs can be used as points of reference. Below, we provide comparisons with NIOSH RELs or other OELs as a point of reference when sharing area air sampling results.

Full-shift area air sampling results for diacetyl and 2,3-pentanedione can be seen in Table C1. We collected 44 full-shift area samples in various locations including the administrative area, café, break room, QC room, green bean storage, roasting, weigh-pack machine, large grinder, small grinder, and finished goods. Full-shift area measurements for diacetyl ranged from 1.4 ppb to 77.3 ppb and 2,3-pentanedione ranged from 0.7 ppb to 50.5 ppb.

The highest full-shift area measurements were collected near the small grinder. Area measurements for diacetyl and 2,3-pentanedione near the small grinder were approximately three to 72 fold higher than other areas measured. Full-shift diacetyl concentrations measured near the small grinder ranged from 31.6 ppb to 77.3 ppb and exceeded the NIOSH REL of 5 ppb diacetyl. Full-shift 2,3 pentanedione concentrations measured near the small grinder ranged from 22.8 ppb to 50.5 ppb and exceeded the NIOSH REL of 9.3 ppb 2,3-pentanedione.

Task-based personal air sampling for diacetyl and 2,3-pentanedione

Task-based personal air sampling results for diacetyl and 2,3-pentanedione can be seen in Table C2. We collected two task-based personal samples on production employees with sample durations ranging from 17 minutes to 19 minutes. Tasks sampled included (1) grinding coffee beans at the small grinder and (2) cleaning chaff out of the roaster. The highest task-based personal measurements for diacetyl and 2,3-pentanedione were collected while an employee ground coffee beans at the small grinder and measured 98.3 ppb for diacetyl and 69.7 ppb for 2,3-pentanedione. Alternatively, diacetyl measurements were 10.9 ppb, and 2,3-pentanedione measurements were 6.2 ppb while an employee cleaned chaff out of the roaster.

Task-based area air sampling for diacetyl and 2,3-pentanedione

Task-based area air sampling results for diacetyl and 2,3-pentanedione can be seen in Table C3. We collected ten task-based area samples with sample durations ranging from 8 minutes to 50 minutes. Tasks sampled included (1) grinding coffee beans at the large grinder with no ventilated enclosure, (2) grinding at the large grinder with the ventilated enclosure, (3) grinding at the small grinder, and (4) packaging ground coffee at the weigh-pack machine. Excluding samples collected inside the ventilated enclosure, the highest task-based area measurements for diacetyl and 2,3-pentanedione were collected while an employee ground coffee at the small grinder and measured 85.2 ppb for diacetyl and 67.2 ppb for 2,3-pentanedione. The second highest measurements for diacetyl and 2,3-pentanedione were collected while an employee ground coffee at the large grinder with no ventilated enclosure and measured 61.1 ppb for diacetyl and 51.0 ppb for 2,3-pentanedione. Task-based area measurements of diacetyl and 2,3-pentanedione were much lower when grinding at the large grinder with a ventilated enclosure with samples collected outside the ventilated enclosure measuring 6.1 ppb for diacetyl and 5.3 ppb for 2,3-pentanedione. A task-based area sample collected while an employee packaged ground coffee at the weigh-pack machine measured 5.7 ppb for diacetyl and 5.9 ppb for 2,3-pentanedione.

Methods: Air sampling for carbon monoxide (CO), carbon dioxide (CO_2), and total volatile organic compounds (VOCs)

We collected area air samples for CO with Dräger Pac® 7000 personal single gas detectors (Lübeck, Germany). We also collected real-time measurements of CO_2 using TSI Incorporated (Shoreview, MN) VelociCalc Model 9555-X Multi-Function Ventilation Meters equipped with Model 982 IAQ probes. Lastly, we also used Tiger VOC detector monitors (10.6 eV photoionization lamp, ION Science, Stafford, TX) to measure concentrations of total VOCs in the air. This sampling was conducted to identify areas where coffee could be releasing VOCs. Areas where higher concentrations of total VOCs were measured helped indicate areas where exposures to alpha-diketones, such as diacetyl and 2,3-pentanedione, were possible.

Task-based continuous air monitoring of CO was also used to assess the effectiveness of a temporary solution to lower CO emissions at the small grinder by utilizing a small fan at the small grinder to dilute and lower CO concentrations in the immediate vicinity of the small grinder. We helped position a small fan at the small grinder so that it would blow emissions from the small grinder away from an employee's breathing zone while performing grinding tasks. We tested this midday on Day 4 of our survey (July 27, 2023), by turning the fan on for 8 minutes, and then off for 9 minutes, while an employee ground multiple 5 lb bags of coffee. A single personal continuous measurement for CO was collected on an employee while they ground coffee at the small grinder with the fan on. Personal CO air samples were also collected using a Dräger Pac 7000 personal single gas detector (Lübeck, Germany).

Results: Air sampling for carbon dioxide (CO_2), carbon monoxide (CO), and total volatile organic compounds (VOCs)

Full-shift continuous area air measurements for CO_2, CO, and total VOCs

A summary of full-shift continuous area air measurements for CO_2, CO, and total VOCs for each day of our survey can be seen in Table C4. CO_2 measurements ranged from 333 ppm to 1,240 ppm. CO measurements ranged from less than 0.1 ppm to 1,521 ppm. A single 10 second measurement (1,521 ppm) at the small grinder exceeded the NIOSH IDLH for CO of 1200 ppm [NIOSH 1994, 2019]. Additionally, measurements of CO at the small grinder exceeded the NIOSH ceiling limit for CO of 200 ppm [NIOSH 2019a] on each day of our survey. CO maximums at the small grinder ranged from 1,041 ppm to 1,521 ppm. The ceiling limit and IDLH value should not be exceeded at any time. Total VOC measurements ranged from less than 1 ppb to 8,349 ppb. The highest total VOC measurement (8,349 ppb) was collected in the area near the small grinder.

Task-based continuous area air measurements for CO

Task-based continuous area air measurements for CO while an employee ground coffee at the small grinder ranged from 2 ppm to 1,172 ppm (Table C5). Area measurements for CO at the small grinder were almost five-fold lower when utilizing the small fan at the small grinder during grinding tasks. We measured an average area concentration of 129 ppm CO when an employee ground multiple 5 lb bags of coffee at the small grinder with the fan turned off. When the fan was on, average area CO levels were reduced to 27.0 ppm for CO while an employee ground multiple 5 lb bags of coffee at the small grinder. Additionally, peak area levels of CO measured at the small grinder were reduced to levels below the NIOSH ceiling limit for CO of 200 ppm when the small fan was used during grinding tasks at the small grinder. The highest peak area measurement for CO when the fan was used during grinding tasks at the small grinder was 191 ppm CO. Conversely, the highest peak area measurement of CO when the fan was off during grinding tasks at the small grinder was 1,172 ppm. The personal continuous measurement for CO collected while an employee ground coffee at the small grinder with the fan on ranged from 3 ppm to a peak of 86 ppm for CO. We note that these measurements of CO at the small grinder were all collected when the overhead ceiling fans were turned on; the overhead fans likely contributed to greater mixing of air and lowering of the intensity of CO concentrations measured at the small grinder overall.

Ventilation Control Installation and Assessment

Methods: Installation and assessment of effectiveness of ventilated enclosure at the large grinder

We constructed a ventilated enclosure at the large grinder on the second day of the survey, after grinding tasks at the large grinder were completed for the day (Figure B1). The ventilated enclosure was designed to capture emissions from the large grinder and exhaust them outside above the first level of the building and away from any pedestrian traffic, subsequently lowering potential exposures to diacetyl, 2,3-pentanedione, and CO while performing grinding tasks at the large grinder. The enclosure was designed with a movable plastic flap that could be rolled and lifted whenever employees needed to access the top of the grinder to dump whole beans from a storage tote into the large grinder. The flap would then be rolled down and closed by the employee prior to initiating each grind. The ventilated enclosure was operated on the third and fourth days of our survey. The exhaust fan inside the enclosure was turned on and operated the entire day on the third and fourth days of our survey.

Figure B1. Ventilated enclosure installed at the large grinder with movable flap rolled up to allow access. Photo by NIOSH.

Results: Assessment of effectiveness of ventilated enclosure at the large grinder

Area measurements of diacetyl and 2,3-pentanedione before and after installation and operation of the ventilated enclosure at the large grinder

All area measurements for diacetyl and 2,3-pentanedione in the production area decreased after the ventilated enclosure at the large grinder was installed and operated, with the exception of the area near the small grinder. Multiple production area measurements for diacetyl were decreased to levels that were below, or within 1 ppb of the NIOSH REL for diacetyl, on days when the ventilated enclosure was operated. With the exception of the area near the small grinder, all area measurements for 2,3-pentanedione were below the NIOSH REL for 2,3-pentanedione. We note that larger amounts of roasted coffee were ground at the small grinder on the last two days of our survey and likely contributed to elevated concentrations of diacetyl and 2,3-pentanedione at the small grinder on the two days when the ventilated enclosure at the large grinder was operating.

Task-based area measurements of diacetyl and 2,3-pentanedione before and after installation and operation of the ventilated enclosure at the large grinder

As described in the results section in the exposure assessment section above, task-based area measurements of diacetyl and 2,3-pentanedione were much lower when grinding at the large grinder with a ventilated enclosure, compared to grinding at the large grinder with no ventilated enclosure. Prior to installation and operation of the ventilated enclosure at the large grinder, task-based area samples collected at the large grinder measured 61.1 ppb for diacetyl and 51.0 ppb for 2,3-pentanedione. After installing and operating the ventilated enclosure, measurements decreased almost 10-fold, with samples collected outside the ventilated enclosure measuring 6.1 ppb for diacetyl and 5.3 ppb for 2,3-pentanedione.

Full-shift continuous area air measurements for CO after installation and operation of the ventilated enclosure at the large grinder

Prior to installing the ventilated enclosure at the large grinder, CO measurements ranged from less than 0.1 ppm to 36 ppm CO at the large unenclosed grinder on a day when grinding was performed (Day 2, Table C4). After the enclosure was installed at the end of Day 2 of our survey, grinding at the large grinder was only performed on Day 4 (Table C4). The average full-shift area measurements for CO on a day when grinding was performed was 4.1 ppm inside the large grinder ventilated enclosure and 1.8 ppm directly outside of the ventilated enclosure. Average area measurements of CO collected specifically during grinding tasks at the large grinder ranged from 17.8 ppm to 36.1 ppm inside the ventilated enclosure to 2.0 ppm to 2.9 ppm directly outside of the ventilated enclosure (Table C6). The highest peak of CO (19 ppm) measured outside of the ventilated enclosure occurred when an employee opened the enclosure flap immediately after the grinding had finished (Table C4).

Employee Health

Methods: Informal interviews

During July 24–27, 2023, we conducted individual informal interviews with 10 staff that included discussions on tasks performed, products used, personal protective equipment worn, work history, and health concerns. For employees who expressed health concerns and who wished to seek additional medical consultation for their health concerns, we provided a list of medical providers with whom they could follow-up. The list of medical providers were based on knowledge among the NIOSH staff of regional providers with familiarity in occupational and pulmonary medicine or providers listed by the Association of Occupational and Environmental Clinics.

Results: Informal interviews

Ten employees participated in the informal interviews and included employees who worked in the production area, administrative area, and café. Tasks reported included various production, administrative, and café tasks. Employees interviewed reported having worked in the coffee industry anywhere from two months to 20 years. One employee reported respiratory symptoms that had progressively worsened since working in the coffee industry. One other employee reported having chronic asthma that had improved since beginning working in the coffee industry, after having had previous employment with outdoors-based jobs. Employees reported voluntarily wearing N95® respirators while cleaning chaff trays at the back of the roaster at the end of their shift.

Discussion

Below, we provide information pertinent to interpreting diacetyl, 2,3-pentanedione, and CO results from our survey and a discussion of what is known about occupational exposure to diacetyl, 2,3-pentanedione, and CO, including potential health effects. We also discuss results from our exposure assessment, our installation and assessment of a ventilated enclosure at the large grinder, and results from informal employee interviews.

Why was NIOSH focused on diacetyl, 2,3-pentanedione, and CO during this survey?

Concerns about potential diacetyl, 2,3-pentanedione, and CO exposure were specifically mentioned in this health hazard evaluation request. Diacetyl, 2,3-pentanedione, other VOCs, and gases such as CO and CO_2 are naturally produced and released during the coffee roasting process [Daglia et al. 2007; Duling et al. 2016; Newton 2002; Nishimura et al. 2003; Raffel and Thompson 2013]. Grinding roasted coffee beans produces a greater surface area for off-gassing (sometimes called degassing) of these compounds [Akiyama et al. 2003] and ground coffee or tasks with ground coffee (e.g., grinding) have been associated with higher exposures to diacetyl, 2,3-pentanedione, and CO [Blackley et al. 2022; Hawley et al. 2017; LeBouf and Aldridge 2019; LeBouf et al. 2020].

Documented health concerns with exposure to diacetyl, 2,3-pentanedione, and CO among coffee production are further discussed below. In addition to measurements for diacetyl, 2,3-pentanedione, and CO, we also collected direct reading measurements of CO_2 and total VOCs to identify areas of off-gassing of vapors and gases from roasted coffee. However, measurements of CO_2 and total VOCs were not collected due to specific health concerns related to CO_2 or total VOC exposures in coffee production. Instead, areas where higher concentrations of CO_2 or total VOCs are measured can help indicate areas where sampling might be necessary to characterize specific exposures to diacetyl, 2,3-pentanedione, and CO. We measured CO_2 and total VOCs as additional metrics to assess (1) areas with higher amounts of vapors and gases from roasted coffee (including other vapors or gases associated with health concerns among coffee production employees, such as diacetyl, 2,3-pentanedione, and CO) and (2) the effectiveness of the ventilated enclosure installed at the large grinder at minimizing emissions of vapors and gases during coffee grinding.

Occupational exposure to diacetyl and 2,3-pentanedione can cause loss of lung function and the lung disease obliterative bronchiolitis [NIOSH 2016]. Some employees at a coffee roasting and packaging facility that used flavorings and had elevated levels of diacetyl and 2,3-pentanedione developed obliterative bronchiolitis [Bailey et al. 2015; CDC 2013; Duling et al. 2016]. Additional information about obliterative bronchiolitis is provided in the section below on obliterative bronchiolitis.

NIOSH has recommended exposure limits (RELs) for diacetyl and 2,3-pentanedione in workplace air (Table D1) [NIOSH 2016]. The NIOSH objective in establishing RELs for diacetyl and 2,3-pentanedione is to reduce the risk of respiratory impairment (decreased lung function) and the severe irreversible lung disease obliterative bronchiolitis associated with occupational exposure to these chemicals. NIOSH RELs are intended to protect workers exposed to diacetyl or 2,3-pentanedione for a 45-year working lifetime. The REL for diacetyl is based on a quantitative risk assessment that necessarily contains assumptions and some uncertainty. Analytical limitations current at the time the NIOSH REL was established were taken into consideration in setting the REL for 2,3-pentanedione. The RELs should be used as a guideline to indicate when steps should be taken to reduce exposures in the workplace.

These exposure limits and the accompanying recommendations for control of exposures were derived from a risk assessment of flavoring-exposed workers. At an exposure equal to the diacetyl REL, the risk of adverse health effects is low. NIOSH estimated about 1 in 1,000 workers exposed to diacetyl levels of 5 ppb as a TWA for 8 hours a day, 40 hours a week for a 45-year working lifetime would develop reduced lung function (defined as forced expiratory volume in one second [FEV1] below the lower limit of normal) as a result of that exposure. NIOSH predicted that around 1 in 10,000 workers exposed to diacetyl at 5 ppb for a 45-year working lifetime would develop more severe lung function reduction (FEV1 below 60% predicted, defined as at least moderately severe by the American Thoracic Society [Pellegrino et al. 2005]). Workers exposed for less time would be at lower risk for adverse lung effects.

CO is a gas produced by combustion. CO is also produced as a result of reactions that take place during coffee roasting and is released during and after roasting and grinding by a process called off-gassing [Anderson et al. 2003; Hawley 2017]. CO can displace oxygen in the blood and deprive a person's brain, heart, and other vital organs of oxygen. Common symptoms of CO exposure are headache, dizziness, nausea, weakness, and confusion; large amounts of CO can cause a person to lose consciousness and die [CDC 2024]. Occupational exposure limits for CO and CO_2 are listed in Table D1, and additional information about occupational exposure limits are provided in Section D of this report.

What is Obliterative Bronchiolitis?

Obliterative bronchiolitis is a serious, often disabling, lung disease that involves scarring of the small airways (i.e., bronchioles). Symptoms of this disease can include cough, shortness of breath on exertion, or wheeze, that do not typically improve away from work [NIOSH 2012]. Occupational obliterative bronchiolitis has been identified in flavoring manufacturing workers and microwave popcorn workers who worked with flavoring chemicals or butter flavorings [Kanwal et al. 2006; Kim et al. 2010; Kreiss 2013]. Obliterative bronchiolitis has also been identified among employees at a coffee roasting and packaging facility that produced unflavored and flavored coffee [CDC 2013]. A NIOSH health hazard evaluation at that facility found diacetyl and 2,3-pentanedione concentrations in the air that were elevated (range: 4.3 ppb to 166 ppb diacetyl; <5.2 ppb to 199 ppb 2,3-pentanedione) and identified three sources: (1) flavoring chemicals added to roasted coffee beans in the flavoring area; (2) grinding unflavored roasted coffee beans and packaging unflavored ground and whole bean roasted coffee in a distinct area of the facility, and (3) storing roasted coffee in hoppers for off-gassing, on a mezzanine above the grinding/packaging process [Duling et al. 2016]. At the time of the previous health hazard evaluation at the other facility that produced unflavored and flavored coffee, employees had excess shortness of breath and obstruction on spirometry, both consistent with undiagnosed lung disease. Respiratory illness was associated with exposure and not limited to the flavoring areas [Bailey et al. 2015]. However, all employees who were diagnosed with obliterative bronchiolitis had worked in the flavoring area. To date, no cases of obliterative bronchiolitis have been reported among employees at coffee roasting and packaging facilities that produce only unflavored coffee.

What were the main results of NIOSH's exposure assessment in July 2023?

Overall, the highest area samples for diacetyl, 2,3-pentanedione, CO, and total VOCs were observed in areas where roasted coffee was ground, and the highest personal measurements for diacetyl and 2,3-pentanedione were observed on production employees on the first two days of our survey, prior to installing and operating the ventilated enclosure at the large grinder. Diacetyl, 2,3-pentanedione, other VOCs, and other compounds such as CO_2 and CO are naturally produced when coffee beans are roasted. As described above, grinding roasted coffee beans produces greater surface area for the off-gassing of these chemicals and previous studies have observed higher levels of diacetyl, 2,3-pentanedione, and CO near sources of ground coffee or during tasks with ground coffee [Akiyama et al. 2003; Anderson et al. 2003; Blackley et al. 2022; Daglia et al. 2007; Hawley et al. 2017; LeBouf et al. 2020; Newton 2002; Nishimura et al. 2003; Raffel and Thompson 2013].

Personal Air Sampling for Diacetyl and 2,3-pentanedione

Six out of seven personal measurements for diacetyl collected on production employees exceeded the NIOSH REL for diacetyl of 5 ppb. Full-shift personal measurements for diacetyl ranged from 1.2 ppb to 12.5 ppb and 2,3-pentanedione ranged from 0.9 ppb to 7.8 ppb. The highest measurements were collected on days prior to installing the ventilated enclosure at the large grinder. All personal samples collected on employees working in the administrative and QC areas (n=6) were below the NIOSH REL for diacetyl of 5 ppb (including one employee who worked in both production and administrative areas). All personal measurements for 2,3-pentanedione were below the NIOSH REL for 2,3-pentanedione of 9.3 ppb.

As noted earlier, the RELs should be used as a guideline to indicate when steps should be taken to reduce exposures in the workplace. The levels of diacetyl we measured in July 2023 are higher than the levels that NIOSH recommends. As described in the quantitative risk assessment from the NIOSH Criteria Document (Tables 5-27 and 5-29) [NIOSH 2016], after a 45-year working lifetime exposure to 10 ppb (a concentration slightly lower than the highest concentration measured at this facility), NIOSH estimated less than 2 in 1,000 workers would develop reduced lung function (FEV1 below the lower limit of normal). NIOSH predicted that around 2 in 10,000 workers exposed to diacetyl at 10 ppb would develop more severe lung function reduction (FEV1 below 60% predicted, defined as at least moderately severe by the American Thoracic Society [Pellegrino et al. 2005]). After a 45-year working lifetime exposure to 20 ppb (a concentration slightly higher than the highest concentration measured at this facility), NIOSH estimated that 3 in 1,000 workers would develop reduced lung function (FEV1 below the 5th percentile). NIOSH predicted that 5 in 10,000 workers exposed to diacetyl at 20 ppb would develop more severe lung function reduction. The effects of a working lifetime exposure at 13 ppb would be between those for 10 ppb and 20 ppb. NIOSH recommends keeping diacetyl concentrations below 5 ppb because at this level, the risk of reduced lung function after a working lifetime of exposure is below 1 in 1000 workers. NIOSH recommends taking steps to reduce diacetyl exposures to below the REL of 5 ppb whenever possible.

Area Air Sampling for Diacetyl and 2,3-Pentanedione

We note here again that because area air samples are not personal air samples collected directly on an employee, the NIOSH RELs are not directly applicable to the full-shift area air sampling results for exposure monitoring purposes. However, area air samples can highlight areas with higher exposure risk, and the RELs can be used as points of reference.

Area sampling results were similar to personal sampling results in that the highest area full-shift and task-based samples were measured in areas where coffee was ground. Full-shift diacetyl concentrations measured near the small grinder ranged from 31.6 ppb to 77.3 ppb and exceeded the NIOSH REL for diacetyl of 5 ppb. Similarly, full-shift 2,3 pentanedione concentrations measured near the small grinder ranged from 22.8 ppb to 50.5 ppb and also exceeded the NIOSH REL for 2,3-pentanedione of 9.3 ppb. Further, the highest task-based area measurements were measured during grinding at the large grinder (prior to installation of ventilated enclosure) and during grinding at the small grinder. Task-based area samples ranged from 23.7 ppb to 61.1 ppb for diacetyl and 18.2 ppb to 51.0 ppb for 2,3-pentanedione during grinding at the large unenclosed grinder. Task-based area samples measured at the small grinder were even higher, with diacetyl measurements ranging from 25.1 ppb to 85.2 ppb and 2,3-pentanedione measurements ranging from 18.7 ppb to 67.2 ppb during grinding at the small grinder.

Area Air Sampling for CO

Similar to results for diacetyl and 2,3-pentanedione, the highest area air measurements for CO were measured at the small grinder during grinding tasks. Full-shift continuous area air measurements of CO collected every 10 seconds at the small grinder ranged from less than 0.1 ppm to 1,521 ppm. Peak measurements of CO collected while multiple 12 oz and 5 lb bags of coffee were ground at the small grinder ranged from 1,041 ppm to 1,521 ppm and exceeded the NIOSH ceiling limit for CO of 200 ppm on all days of our survey. A single 10-second measurement (1,521 ppm) on the first day of our survey exceeded the NIOSH IDLH value for CO of 1,200 ppm. The IDLH value of 1,200 ppm is based on studies that suggested a concentration between 1,500 and 2,000 ppm might be a dangerous concentration after 1 hour [NIOSH 2014]. A 30-minute exposure to 1,200 ppm CO can produce a carboxyhemoglobin level of 10%–13% which is associated with headaches [NIOSH 2014]. We note that carboxyhemoglobin is formed in the blood after exposure to CO, and levels of carboxyhemoglobin in the blood are used to assess CO poisoning. Increasing CO exposure will lead to more carboxyhemoglobin which decreases the ability for the blood to deliver oxygen to bodily tissues and organs, resulting in health effects. Although the CO level that exceeded the IDLH was brief, neither the NIOSH ceiling limit nor IDLH value for CO should be exceeded at any time.

As a temporary solution, a small fan was positioned at the small grinder to blow emissions away from the breathing zone of employees performing grinding tasks and lowered average area CO levels at the small grinder by almost five-fold and lowered peak measurements of CO to levels just below the NIOSH ceiling limit. However, we note this was based on only one 17-minute sampling period at the small grinder (8 minutes with the fan on and 9 minutes with the fan off), and our single test of the fan on versus off might not apply to all times when the small grinder is used. It is possible the NIOSH ceiling limit can still be exceeded when using the small grinder for grinding tasks due to other factors that were not tested, including grinding different roast levels of coffee (i.e., light, medium, or dark roasts) or different total quantities of coffee (i.e., more than the number of 5 lb bags that were ground in the 8 minutes we sampled).

How effective was the ventilated enclosure installed at the large grinder?

Overall, the ventilated enclosure installed and operated at the large grinder successfully reduced all personal and area air measurements for diacetyl, 2,3-pentanedione, and CO. After the ventilated enclosure at the large grinder was installed and operated, the highest personal full-shift measurements for diacetyl and 2,3-pentanedione collected on production employees were reduced from 12.5 ppb to 8.2 ppb for diacetyl and 7.7 ppb to 4.8 ppb for 2,3-pentanedione. Similarly, the highest personal full-shift measurements for diacetyl and 2,3-pentanedione collected on roaster operators were reduced from 10.7 ppb to 8.8 ppb for diacetyl and 7.8 ppb to 5.4 ppb for 2,3-pentanedione after the ventilated enclosure at the large grinder was installed. These results indicate the ventilated enclosure installed and operated at the large grinder increased the total amount of air exhausted from the production areas and contributed to lower levels of personal exposures to diacetyl and 2,3-pentanedione in the production areas.

Similarly, area measurements of diacetyl at the large grinder were reduced to levels below the NIOSH REL after the ventilated enclosure was installed. Measurements of diacetyl and 2,3-pentanedione collected inside and outside of the ventilated enclosure during a grinding task indicated the ventilated enclosure reduced diacetyl and 2,3-pentanedione levels at the large grinder by almost 16-fold. The ventilated enclosure at the large grinder also resulted in approximately seven to 12-fold lower levels of CO during grinding tasks at the large grinder. Area measurements of CO collected specifically during grinding tasks at the large grinder ranged from 17.8 ppm to 36.1 ppm inside the ventilated enclosure to 2.0 ppm to 2.9 ppm directly outside of the ventilated enclosure.

All production area measurements for diacetyl and 2,3-pentanedione, except for measurements at the small grinder, were reduced after the ventilated enclosure at the large grinder was installed. We note that more grinding of roasted coffee was performed at the small grinder on the days after the ventilated enclosure was installed at the large grinder, and the increased amount of ground coffee likely contributed to elevated levels of diacetyl and 2,3-pentanedione at the small grinder on days after the ventilated enclosure at the large grinder was installed and operated.

It is important to note that the grinder enclosure we installed during this survey was constructed using lumber, plastic sheeting, and a ducted blower commonly used to ventilate confined spaces. The enclosure system was not designed or operated to meet any predefined exposure reduction goals. It was installed as a temporary enclosure to demonstrate how a ventilated enclosure could reduce levels of diacetyl, 2,3-pentanedione, and CO emitted from grinding tasks at the large grinder. Although the enclosure proved effective at reducing exposures in nearly all of the production space, additional reductions could be achieved by properly designing and constructing a more permanent, airtight enclosure around the large grinder.

Are there other health concerns associated with working in coffee production that I should be aware of?

Green and roasted coffee dust and castor beans (from cross-contamination of bags used to transport coffee) are known risk factors for occupational asthma [Figley and Rawling 1950; Karr et al. 1978; Thomas et al. 1991; Zuskin et al. 1979, 1985]. Occupational asthma refers to asthma that is brought on by workplace exposures. Work-related asthma includes occupational asthma as well as asthma or made worse by ("work-exacerbated asthma" or "work-aggravated asthma") workplace exposures [Henneberger et al. 2011; NIOSH 2024; OSHA 2014; Tarlo 2016; Tarlo and Lemiere 2014]. It includes asthma attributable to sensitizers, which cause disease through immune (allergic) mechanisms, and asthma attributable to irritants, which cause disease through non-immune mechanisms. Symptoms of work-related asthma include episodic shortness of breath, cough, wheeze, and chest tightness. The symptoms can begin early in a work shift, towards the end of a shift, or hours after a shift. They generally, but do not always, improve or remit during periods away from work, such as on weekends or holidays. Persons who become sensitized (develop an immune reaction) to coffee dust can subsequently react to relatively low concentrations in the air. Others can experience irritant-type symptoms from exposure to coffee dust [Oldenburg et al. 2009].

Limitations

Our evaluation has several limitations. First, our sampling was limited to four days at the coffee roasting and packaging facility and might not represent all working conditions and potential exposures. For example, the frequency and duration of grinding tasks at the large grinder vary depending on the production needs for any given day. Although we captured variability in use of the large grinder during the four days of our survey, our sampling might not represent all working conditions and potential exposures. Additionally, 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 transferred to other locations or were not present at the facility at the time of the evaluation. Further, interviews could have been affected by recall biases.

Conclusions

Overall, the highest area samples for diacetyl, 2,3-pentanedione, CO, and total VOCs were observed in areas where roasted coffee was ground, and in general, the highest air measurements were collected on days prior to installing the ventilated enclosure at the large grinder. Six out of seven personal measurements for diacetyl collected on production employees exceeded the NIOSH REL for diacetyl of 5 ppb; all personal measurements for 2,3-pentanedione were below the NIOSH REL for 2,3-pentanedione of 9.3 ppb. Full-shift personal measurements for diacetyl ranged from 1.2 ppb to 12.5 ppb, and 2,3-pentanedione ranged from 0.9 ppb to 7.8 ppb. Peak area measurements of CO collected while multiple bags of coffee were ground at the small grinder exceeded the NIOSH ceiling limit for CO of 200 ppm on all days of our survey. A single 10-second measurement of 1,521 ppm on the first day of our survey exceeded the NIOSH IDLH value for CO of 1,200 ppm. Additionally, the highest task-based area measurements for diacetyl and 2,3-pentanedione were observed at the small grinder (range: 25.1 ppb to 85.2 ppb for diacetyl and 18.7 ppb to 67.2 ppb for 2,3-pentanedione during grinding at the small grinder). Overall, enclosing and ventilating the large grinder successfully reduced all personal and area air measurements for diacetyl, 2,3-pentanedione, and CO, with personal measurements for diacetyl being reduced to levels that approached the NIOSH REL for diacetyl.

Attribution Statement

N95 and NIOSH Approved are certification marks of the U.S. Department of Health and Human Services (HHS) registered in the United States and several international jurisdictions.

Section C: Tables

Table C1. Time-weighted average full-shift personal and area air sampling results by location, NIOSH survey, July 2023							
Analyte	**Sample Type**	**Location***	**N**	**Above LOD N (%)**	**Minimum Concentration (ppb)**	**Maximum Concentration (ppb)**	**Above REL N (%)**
Diacetyl	Personal	Administrative	4	4 (100%)	1.2	3.8	0 (0%)
Diacetyl	Personal	Production and Administrative	1	1 (100%)	2.7	2.7	0 (0%)
Diacetyl	Personal	QC room	1	1 (100%)	2.8	2.8	0 (0%)
Diacetyl	Personal	Production, pre-enclosure	1	1 (100%)	12.5	12.5	1 (100%)
Diacetyl	Personal	Production, post-enclosure	2	2 (100%)	6.1	8.2	2 (100%)
Diacetyl	Personal	Roasting, pre-enclosure	2	2 (100%)	3.8	10.7	1 (50%)
Diacetyl	Personal	Roasting, post-enclosure	2	2 (100%)	5.2	8.8	2 (100%)
Diacetyl	Area	Office area	4	4 (100%)	1.8	2.5	N/A
Diacetyl	Area	Café	4	4 (100%)	2.6	3.1	N/A
Diacetyl	Area	Break room	4	4 (100%)	1.7	2.4	N/A
Diacetyl	Area	QC room (table with QC grinder)	4	4 (100%)	1.4	7.8	N/A
Diacetyl	Area	Green bean storage, pre-enclosure	2	2 (100%)	6.7	9.6	N/A
Diacetyl	Area	Green bean storage, post-enclosure	2	2 (100%)	4.5	5.4	N/A
Diacetyl	Area	Roasting, pre-enclosure	2	2 (100%)	6.5	9.3	N/A
Diacetyl	Area	Roasting, post-enclosure	2	2 (100%)	3.5	5.6	N/A
Diacetyl	Area	Weigh-pack machine, pre-enclosure	2	2 (100%)	7.3	9.7	N/A
Diacetyl	Area	Weigh-pack machine, post-enclosure	2	2 (100%)	5.5	6.2	N/A
Diacetyl	Area	Near large grinder, pre-enclosure	4	4 (100%)	2.7	6.8	N/A
Diacetyl	Area	Near large grinder, post-enclosure	2	2 (100%)	1.9	2.5	N/A
Diacetyl	Area	Near large grinder, inside enclosure	2	2 (100%)	4.6	10.0	N/A
Diacetyl	Area	Near small grinder, pre-enclosure	2	2 (100%)	31.6	45.6	N/A
Diacetyl	Area	Near small grinder, post-enclosure	2	2 (100%)	36.4	77.3	N/A
Diacetyl	Area	Finished goods, pre-enclosure	2	2 (100%)	6.9	10.4	N/A
Diacetyl	Area	Finished goods, post-enclosure	2	2 (100%)	5.1	6.8	N/A

Table C1 (continued). Time-weighted average full-shift personal and area air sampling results by location, NIOSH survey, July 2023							
Analyte	**Sample Type**	**Location***	**N**	**Above LOD N (%)**	**Minimum Concentration (ppb)**	**Maximum Concentration (ppb)**	**Above REL N (%)**
2,3-Pentanedione	Personal	Administrative	4	4 (100%)	0.9	3.6	0 (0%)
2,3-Pentanedione	Personal	Production and Administrative	1	1 (100%)	2.1	2.1	0 (0%)
2,3-Pentanedione	Personal	QC room	1	1 (100%)	1.6	1.6	0 (0%)
2,3-Pentanedione	Personal	Production, pre-enclosure	1	1 (100%)	7.7	7.7	0 (0%)
2,3-Pentanedione	Personal	Production, post-enclosure	2	2 (100%)	3.8	4.8	0 (0%)
2,3-Pentanedione	Personal	Roasting, pre-enclosure	2	2 (100%)	1.9	7.8	0 (0%)
2,3-Pentanedione	Personal	Roasting, post-enclosure	2	2 (100%)	4.6	5.4	0 (0%)
2,3-Pentanedione	Area	Office area	4	4 (100%)	1.2	2.1	N/A
2,3-Pentanedione	Area	Café	4	4 (100%)	1.9	3.2	N/A
2,3-Pentanedione	Area	Break room	4	4 (100%)	1.7	2.1	N/A
2,3-Pentanedione	Area	QC room (table with QC grinder)	4	4 (100%)	0.7	5.8	N/A
2,3-Pentanedione	Area	Green bean storage, pre-enclosure	2	2 (100%)	4.1	6.8	N/A
2,3-Pentanedione	Area	Green bean storage, post-enclosure	2	2 (100%)	3.4	3.5	N/A
2,3-Pentanedione	Area	Roasting, pre-enclosure	2	2 (100%)	4.3	6.6	N/A
2,3-Pentanedione	Area	Roasting, post-enclosure	2	2 (100%)	2.6	3.8	N/A
2,3-Pentanedione	Area	Weigh-pack machine, pre-enclosure	2	2 (100%)	4.8	7.1	N/A
2,3-Pentanedione	Area	Weigh-pack machine, post-enclosure	2	2 (100%)	3.9	3.9	N/A
2,3-Pentanedione	Area	Near large grinder, pre-enclosure	4	4 (100%)	1.6	4.9	N/A
2,3-Pentanedione	Area	Near large grinder, post-enclosure	2	2 (100%)	1.3	1.6	N/A
2,3-Pentanedione	Area	Near large grinder, inside enclosure	2	2 (100%)	2.8	7.0	N/A
2,3-Pentanedione	Area	Near small grinder, pre-enclosure	2	2 (100%)	22.8	27.7	N/A
2,3-Pentanedione	Area	Near small grinder, post-enclosure	2	2 (100%)	26.0	50.5	N/A
2,3-Pentanedione	Area	Finished goods, pre-enclosure	2	2 (100%)	3.6	7.3	N/A
2,3-Pentanedione	Area	Finished goods, post-enclosure	2	2 (100%)	3.9	4.1	N/A

Note: NIOSH=National Institute for Occupational Safety and Health; N=number of samples; Above LOD N (%)=number and percentage of samples above limit of detection (LOD); Above REL=number of samples above the NIOSH recommended exposure limit (REL); ppb=parts per billion; N/A indicates that NIOSH RELs are specified for personal air samples, and area air samples cannot be used for direct comparisons with RELs; “Production Area” location includes employees that were cross-trained and performed tasks at different areas; “Pre-enclosure” indicates samples that were collected prior to installing and operating the ventilated enclosure at the large grinder; “Post-enclosure” indicates samples that were collected on days when the ventilated enclosure at the large grinder was operating.

Table C2. Summary of task-based personal air sampling results by task, NIOSH survey, July 2023						
Analyte	**Personal Task**	**N**	**Above LOD N (%)**	**Minimum Concentration (ppb)**	**Maximum Concentration (ppb)**	**Sample Duration (minutes)**
Diacetyl	Grind coffee beans at small grinder	1	1 (100%)	98.3	98.3	17
Diacetyl	Cleaning chaff out of roaster	1	1 (100%)	10.9	10.9	19
2,3-Pentanedione	Grind coffee beans at small grinder	1	1 (100%)	69.7	69.7	17
2,3-Pentanedione	Cleaning chaff out of roaster	1	1 (100%)	6.2	6.2	19
Note: NIOSH=National Institute for Occupational Safety and Health; N=number of samples; Above LOD N (%)=number and percentage of samples above limit of detection (LOD); ppb=parts per billion.						

Table C3. Summary of task-based area air sampling results by task, NIOSH survey, July 2023						
Analyte	**Area Task**	**N**	**Above LOD N (%)**	**Minimum Concentration (ppb)**	**Maximum Concentration (ppb)**	**Mean Sample Duration (Range, in minutes)**
Diacetyl	Grinding at large grinder, no ventilated enclosure	2	2 (100%)	23.7	61.1	29 (8–50)
Diacetyl	Grinding at large grinder, outside of ventilated enclosure	1	1 (100%)	6.1	6.1	32
Diacetyl	Grinding at large grinder, inside of ventilated enclosure	1	1 (100%)	96.7	96.7	32
Diacetyl	Grinding at small grinder	5	5 (100%)	25.1	85.2	14 (8–20)
Diacetyl	Packaging ground coffee at weigh-pack	1	1 (100%)	5.7	5.7	46
2,3-Pentanedione	Grinding at large grinder, no ventilated enclosure	2	2 (100%)	18.2	51.0	29 (8–50)
2,3-Pentanedione	Grinding at large grinder, outside of ventilated enclosure	1	1 (100%)	5.3	5.3	32
2,3-Pentanedione	Grinding at large grinder, inside of ventilated enclosure	1	1 (100%)	78.2	78.2	32
2,3-Pentanedione	Grinding at small grinder	5	5 (100%)	18.7	67.2	14 (8–20)
2,3-Pentanedione	Packaging ground coffee at weigh-pack	1	1 (100%)	5.9	5.9	46
Note: NIOSH=National Institute for Occupational Safety and Health; N=number of samples; Above LOD N (%)=number and percentage of samples above limit of detection (LOD); ppb=parts per billion.						

Table C4. Summary of full-shift continuous area air monitoring results for carbon dioxide (CO_2), carbon monoxide (CO), and total volatile organic compounds (VOCs), NIOSH survey, July 2023

Location, Day of Survey	CO_2 (ppm) Mean (Range)	CO (ppm) Mean (Range)	Total VOC (ppb) Mean (Range)
Roaster, Day 1	—	3.7 (1–8)	—
Roaster, Day 2	—	3.1 (<0.1–8)	—
Roaster, Day 3	—	1.7 (<0.1–9)	—
Roaster, Day 4	—	0.9 (<0.1–4)	—
Weigh-pack machine, Day 1	707 (639–922)	2.2 (<0.1–7)	23 (<1–241)
Weigh-pack machine, Day 2	620 (517–803)	3.5 (<0.1–9)	95 (<1–633)
Weigh-pack machine, Day 3	—	1.8 (<0.1–6)	—
Weigh-pack machine, Day 4	—	1.1 (<0.1–11)	—
Small grinder, Day 1	—	6.4 (<0.1–1,521)	—
Small grinder, Day 2	—	6.4 (<0.1–1,041)	125 (<1–8,349)
Small grinder, Day 3	514 (463–676)	16.9 (<0.1–1,195)	36 (<1–3,461)
Small grinder, Day 4	524 (456–1,034)	5.9 (<0.1–1,172)	72 (<1–3,202)
Near large unenclosed grinder, Day 1 *note: no grinding performed	763 (333–973)	2.9 (<0.1–7)	57 (<1–177)
Near large unenclosed grinder, Day 2	725 (575–1,240)	2.1 (<0.1–36)	114 (<1–3,716)
Near large enclosed grinder (outside ventilated enclosure), Day 3 *note: no grinding performed	639 (572–866)	3.2 (<0.1–7)	25 (<1–141)
Near large enclosed grinder (outside ventilated enclosure), Day 4	647 (583–1,012)	1.8 (<0.1–19)	57 (<1–3,116)
Inside ventilated enclosure at large grinder, Day 3 *note: no grinding performed	—	2.1 (<0.1–7)	21 (<1–117)
Inside ventilated enclosure at large grinder, Day 4	—	4.1 (<0.1–52)	171 (<1–5,576)

Note: NIOSH=National Institute for Occupational Safety and Health; CO_2=carbon dioxide measurements collected using TSI Incorporated Velocicalc Model 9555-X Multi-Function Ventilation Meters equipped with Model 982 IAQ probes; CO=carbon monoxide measurements using a Dräger Pac® 7000 personal single gas detectors; VOC=volatile organic compounds measurements collected using Tiger VOC detector monitors; ppm=parts per million; ppb=parts per billion; "-" indicates the instrument was not used to record measurements at this location; "<" indicates less than.

Table C5. Summary of task-based continuous air measurements for carbon monoxide (CO) at the small grinder with the small fan turned on or turned off, NIOSH July 2023				
Type of Sample	**Work Area**	**Task Description**	**CO (ppm) Mean (range)**	**Sample Duration, in minutes**
Area	Small grinder	Grinding 5 lb and 12 oz bags of coffee at the small grinder, small fan off	129 (3–1,172)	8
Area	Small grinder	Grinding 5 lb and 12 oz bags of coffee at the small grinder, small fan on	27 (2–191)	8
Personal	Small grinder	Grinding 5 lb and 12 oz bags of coffee at the small grinder, small fan on	14 (3–86)	4
Note: NIOSH=National Institute for Occupational Safety and Health; CO=carbon monoxide; ppm=parts per million; lb=pound; oz=ounce.				

Table C6. Continuous area air monitoring results for carbon monoxide (CO) inside and outside of the ventilated enclosure during grinding tasks at the large grinder, NIOSH survey, July 2023

CO (ppm) measurements outside the ventilated enclosure during grinding*, Mean (Range)	CO (ppm) measurements inside the ventilated enclosure during grinding, Mean (Range)	Sample Duration, in Minutes
2.9 (2–4)	36.1 (3–52)	8
2.6 (2–3)	17.8 (3–30)	5
2.0 (1–3)	21.0 (3–28)	7

*Results in each row are for a single grinding task at the large grinder which consisted of grinding a tote of approximately 37 pounds of coffee.

Note: CO=carbon monoxide; ppm=parts per million.

Section D: Occupational Exposure Limits

NIOSH investigators refer to mandatory (legally enforceable) and recommended occupational exposure limits (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 permissible exposure limits [29 CFR 1910 for general industry; 29 CFR 1926 for construction industry; and 29 CFR 1917 for maritime industry] called permissible exposure limits (PELs) [OSHA 2021]. These legal limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH recommended exposure limits (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 2020]. 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 includes 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 2025].

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.

Occupational Exposure Limits for Diacetyl, 2,3-Pentanedione, and Carbon Monoxide

Table D1. Exposure limits for compounds sampled during the NIOSH survey, July 2023

Compound	OSHA*	ACGIH		NIOSH		
	PEL	TLV	STEL	REL	STEL	IDLH
Diacetyl	—	10 ppb	20 ppb	5 ppb†	25 ppb	—
2,3-Pentanedione	—	—	—	9.3 ppb†	31 ppb	—
Carbon dioxide‡	5,000 ppm	5,000 ppm	30,000 ppm	5,000 ppm	30,000 ppm	40,000 ppm
Carbon monoxide‡	50 ppm	25 ppm	—	35 ppm	200 ppm (ceiling limit)§	1,200 ppm

Note: OSHA=Occupational Safety and Health Administration; ACGIH=American Conference of Governmental Industrial Hygienists; NIOSH=National Institute for Occupational Safety and Health; PEL=permissible exposure limit; STEL=short-term exposure limit; TLV=threshold limit value; REL=recommended exposure limit; IDLH=immediately dangerous to life or health; ppb=parts per billion; ppm=parts per million; "-"=no exposure limit available.
*There are no OSHA STEL values for the compounds in the table.
†The NIOSH RELs for diacetyl and 2,3-pentanedione are time-weighted averages for up to an 8-hour day, during a 40-hour workweek.
‡OSHA and NIOSH occupational exposure limits [NIOSH 2019a,b; OSHA 2024a,b] are designed for occupational exposure measurements in manufacturing and other trades that have potential sources of carbon dioxide or carbon monoxide (e.g., coffee roasting, welding, vehicle exhaust, diesel engine exhaust). For reference and context, typical levels of carbon monoxide in offices are 0–5 ppm. In office spaces, carbon dioxide generally should not be greater than 600 ppm above outdoor carbon dioxide levels; this typically corresponds to indoor concentrations below 1000 ppm [ANSI/ASHRAE 2022; ANSI/ASHRAE 2023].
§This is the NIOSH ceiling exposure limit for carbon monoxide. A ceiling concentration should not be exceeded at any time.

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