Evaluation of exposures at a coffee roasting, flavoring, and packaging facility

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Contents

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

Highlights of this Evaluation

The Health Hazard Evaluation Program of the National Institute for Occupational Safety and Health received a request from management at a coffee roasting, flavoring, and packaging facility regarding concerns about potential health effects from exposure to diacetyl, 2,3-pentanedione, and other alpha-diketones during coffee roasting, grinding, and flavoring of coffee.

What We Did

- We visited the coffee roasting, flavoring, and packaging facility during May 1–2, 2018.
- We collected full-shift (hours), task (minutes), and instantaneous (seconds) air samples to measure concentrations of diacetyl, 2,3-pentanedione, and 2,3-hexanedione over multiple days.
- We measured real-time air levels of carbon monoxide and carbon dioxide.
- We assessed the ventilation system at the facility.

What We Found

- None of the personal full-shift air sampling was above the recommended exposure limit of 5 parts per billion for diacetyl or 9.3 parts per billion for 2,3-pentanedione. The highest measured concentrations (1.3 parts per billion diacetyl; 1.6 parts per billion 2,3-pentanedione) were measured on a packaging operator.
- Short-term personal air sampling was higher for tasks involving flavoring coffee (maximum 13.7 parts per billion 2,3-pentanedione) and grinding roasted coffee beans (maximum 14.9 parts per billion diacetyl and 12.8 parts per billion 2,3-pentanedione).
- Instantaneous samples collected while an employee ground unflavored coffee were as high as 106 parts per billion for diacetyl and 76.5 parts per billion for 2,3-pentanedione.

We evaluated the airborne exposures to the alpha-diketones diacetyl, 2,3-pentanedione, and 2,3-hexanedione, other volatile organic compounds, carbon monoxide, and carbon dioxide among employees at a coffee roasting, flavoring, and packaging facility. None of the employees had personal full-shift exposures that exceeded the NIOSH recommended exposure limit for diacetyl or 2,3-pentanedione. Personal air sampling during short-term tasks identified grinding roasted coffee beans and flavoring coffee as tasks with higher exposures to alpha-diketones than other tasks. No short-term samples exceeded the recommended short-term exposure limit for diacetyl or 2,3-pentanedione. Continuous air sampling identified peak exposures to carbon monoxide during grinding of roasted coffee. We recommend training employees about workplace hazards. We also recommend engineering controls to reduce exposures to diacetyl, 2,3-pentanedione, and carbon monoxide by the packaging grinders.

- Continuous air sampling identified peak exposures to carbon monoxide during grinding of roasted coffee; carbon monoxide measurements did not exceed occupational exposure limits.
- When the exhaust fan in the adjacent business was turned on, but the flavoring area fan was left off, the flavoring area was under positive pressure to the separate business.

What the Employer Can Do

- Ensure employees understand potential hazards (e.g., diacetyl, 2,3-pentanedione, carbon monoxide, carbon dioxide, green and roasted coffee dust) in the workplace and how to protect themselves.
- Continue to keep all doors between the production and non-production areas closed at all times.
- Ensure the exhaust fan in the flavoring area is always turned on whenever flavoring tasks are performed in the flavoring area to maintain consistent negative pressure in the flavoring area.
- Consider installing local exhaust ventilation at the 5-pound and 300-pound packaging grinders to reduce air concentrations of alpha-diketones (diacetyl and 2,3-pentanedione) and carbon monoxide during grinding of roasted coffee.
- Make N95 disposable filtering-face piece respirators available for voluntary use for protection against dust exposure when emptying burlap bags of green beans, cleaning the exhaust system of chaff, emptying the chaff containers, or cleaning the green bean storage area.
- Encourage employees to report new, worsening, or ongoing respiratory symptoms to their personal healthcare providers and to a designated individual at the workplace.
- Institute a medical monitoring program for all employees who work in or enter areas where coffee is flavored. Employees who work in or enter these areas for 40 or more hours per year should be included in the medical monitoring program.

What Employees Can Do

- Use any local exhaust ventilation as instructed by your employer after it is installed.
- Some employees might wish to use N95 disposable filtering-facepiece respirators when emptying burlap bags of green beans, when cleaning the exhaust system of chaff, when emptying the chaff containers, or when cleaning the green bean storage area.
- Report new, persistent, or worsening respiratory symptoms to your personal healthcare provider(s) and, as instructed, to a designated individual at your workplace.
- Participate in your employer's medical monitoring program as instructed by your employer.

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Abbreviations

ACGIH®	American Conference of Governmental Industrial Hygienists
CFR	Code of Federal Regulations
CO	Carbon monoxide
CO_2	Carbon dioxide
FEV_1	Forced expiratory volume in one second
IDLH	Immediately dangerous to life or health
LOD	Limit of detection
mL	Milliliter
mL/min	Milliliter per minute
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
ppb	Parts per billion
ppm	Parts per million
QC	Quality control
REL	Recommended exposure limit
RH	Relative humidity
STEL	Short-term exposure limit
TLV®	Threshold limit value
TWA	Time-weighted average
VOC	Volatile organic compound

Summary

In February 2018, the Health Hazard Evaluation Program of the National Institute for Occupational Safety and Health received a request from management at a coffee roasting, flavoring, and packaging facility regarding concerns about potential health effects from exposure to diacetyl, 2,3-pentanedione, and other alpha-diketones during coffee roasting, grinding, and flavoring of coffee. In May 2018, we conducted an industrial hygiene survey and ventilation assessment at the facility. The industrial hygiene survey consisted of the collection of air samples for the analysis of diacetyl, 2,3-pentanedione, and 2,3-hexanedione. We used continuous monitoring instruments to monitor total volatile organic compounds, carbon monoxide, carbon dioxide, temperature, and relative humidity in specific areas and during tasks.

None of the eight full-shift personal samples collected during the industrial hygiene survey exceeded the recommended exposure limits of 5 parts per billion for diacetyl or 9.3 parts per billion for 2,3-pentanedione. Grinding roasted coffee beans and flavoring roasted beans resulted in relatively higher air concentrations of diacetyl and 2,3-pentanedione than other tasks. We observed high instantaneous levels of diacetyl and 2,3-pentanedione during grinding of unflavored coffee. Continuous air sampling identified peak exposures to carbon monoxide during grinding of roasted coffee; however, carbon monoxide measurements did not exceed occupational exposure limits. Carbon dioxide levels were low throughout most of the facility. We recommend implementing local exhaust ventilation near the packaging grinders, and training employees about workplace hazards.

Introduction

In February 2018, the National Institute for Occupational Safety and Health (NIOSH) received a management request for a health hazard evaluation at a coffee roasting, flavoring, and packaging facility regarding potential employee exposure to diacetyl during coffee processing. In May 2018, we conducted an industrial hygiene survey and ventilation assessment at the facility. We collected area and personal breathing zone air samples for volatile organic compounds (VOCs), including diacetyl, 2,3-pentanedione, and 2,3-hexanedione. We also monitored and recorded carbon monoxide (CO), carbon dioxide (CO_2), and total VOCs.

Background

Diacetyl and 2,3-Pentanedione

Diacetyl (2,3-butanedione) and 2,3-pentanedione (acetyl propionyl) are VOCs known as alpha-diketones that are added as ingredients in food flavorings used in some food products such as microwave popcorn, bakery mixes, and flavored coffee [Day et al. 2011; Kanwal et al. 2006; Bailey et al. 2015]. Diacetyl, 2,3-pentanedione, other VOCs, and gases such as CO and CO_2 are naturally produced and released during the coffee roasting process [Duling et al. 2016; Raffel and Thompson 2013; Daglia et al. 2007; Nishimura et al. 2003; Newton 2002]. Grinding roasted coffee beans produces a greater surface area for off-gassing (sometimes called degassing) of these compounds [Akiyama et al. 2003]. Often, coffee roasting facilities package newly roasted coffee in permeable bags or in bags fitted with one-way valves to allow the coffee to off-gas after it is packaged. Sometimes, newly roasted coffee is placed in bins or containers and allowed to off-gas before packaging.

NIOSH has recommended exposure limits (RELs) for diacetyl and 2,3-pentanedione in workplace air (Table 1) [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 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 parts per billion (ppb) as a time-weighted average (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 [FEV_1] 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 (FEV_1 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.

2,3-Hexanedione

2,3-Hexanedione is also an alpha-diketone sometimes used as a substitute for diacetyl and is produced naturally during coffee roasting. In a study using animals, there was some evidence that 2,3-hexanedione might also damage the lungs, but it appeared to be less toxic than diacetyl and 2,3-pentanedione [Morgan et al. 2016]. There are no established occupational exposure limits for 2,3-hexanedione.

Carbon Monoxide and Carbon Dioxide

CO and CO_2 are gases produced by combustion. They are also produced as a result of reactions that take place during coffee roasting. These gases are released during and after roasting and grinding by a process called off-gassing [Anderson et al. 2003; Hawley 2017]. High exposures to CO and CO_2 can cause headache, dizziness, fatigue, nausea, altered mentation, rapid breathing, impaired consciousness, coma, and death [Newton 2002; Nishimura et al. 2003; Langford 2005; CDC 2013a; Raffel and Thompson 2013; Rose et al. 2017]. Occupational exposure limits for CO and CO_2 are listed in Table 1.

Exposure Limits

We use mandatory (legally enforceable) and recommended occupational exposure limits (OELs) when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures.

<u>Occupational Safety and Health Administration (OSHA) [Mandatory]</u>

The U.S. Department of Labor's OSHA permissible exposure limits (PELs) are legal limits that are enforceable in workplaces covered under the Occupational Safety and Health Act. OSHA PELs represent the legal maximum for a TWA exposure to a physical or chemical agent over a work shift [OSHA 2018]. OSHA short-term exposure limits (STELs) are the legal maximum average exposure for a 15-minute time period. Some chemicals also have an OSHA ceiling value which represent levels that must not be exceeded at any time. Currently, there are no PELs for diacetyl, 2,3-pentanedione, or 2,3-hexanedione. For substances for which an OSHA PEL has not been issued, violation of the OSHA General Duty Clause can be considered using available occupational exposure references and recommendations [OSHA 1993; OSHA 2003], such as the American Conference of Governmental Industrial Hygienists (ACGIH®) Threshold Limit Values (TLVs®) and NIOSH RELs.

<u>American Conference of Governmental Industrial Hygienist (ACGIH) [Recommendations]</u>

ACGIH is a professional, not-for-profit scientific association that reviews existing published, peer-reviewed scientific literature and publishes recommendations for levels of substances in air based on an 8-hour workday and 40-hour workweek. These recommendations are called threshold limit values (TLVs) [ACGIH 2018a]. ACGIH TLVs are not standards; they are health-based guidelines derived from scientific and toxicological information. ACGIH provides TLV-TWA guidelines that are levels that should not be exceeded during any 8-hour workday of a 40-hour workweek. ACGIH also provides TLV-STEL guidelines that are 15-minute exposure levels that should not be exceeded during a workday. Exposures above the TLV-TWA but less than the TLV-STEL should be (1) less than 15 minutes, (2) occur no more than four times a day, and (3) be at least 60 minutes between exposures [ACGIH 2018a]. Additionally, ACGIH provides TLV-Ceiling values which are levels that should not be exceeded at any time during a work shift. The ACGIH TLV-TWA for diacetyl is 10 ppb. The TLV-STEL for diacetyl is 20 ppb. Currently, there is no TLV-TWA or TLV-STEL for 2,3-pentanedione. ACGIH has placed 2,3-pentanedione on the 2017 list of Chemical Substances and Other Issues Under Study [ACGIH 2018b].

<u>National Institute for Occupational Safety and Health (NIOSH) [Recommendations]</u>
NIOSH provides RELs as TWA concentrations that should not be exceeded over an 8 or 10-hour work shift, during a 40-hour workweek [NIOSH 2010]. RELs are intended to be protective over a 45-year working lifetime. NIOSH also provides STELs that are 15-minute TWA exposures that should not be exceeded at any time during a workday [NIOSH 2016]. Some chemicals have ceiling values that are concentrations that should not be exceeded at any time [NIOSH 2016].

For some chemicals, NIOSH has established an Immediately Dangerous to Life or Health (IDLH) value. An IDLH value is a concentration of an air contaminant that can cause death or immediate or delayed permanent adverse health effects, or prevent escape from such an environment. Currently, NIOSH has RELs and STELs for diacetyl and 2,3-pentanedione. NIOSH does not have a REL or a STEL for 2,3-hexanedione. NIOSH does not have ceiling limits or IDLH values for diacetyl, 2,3-pentanedione, or 2,3-hexanedione.

For diacetyl and 2,3-pentanedione, the NIOSH RELs are 5.0 ppb and 9.3 ppb, respectively, as a TWA for up to an 8-hour workday during a 40-hour workweek (Table 1). The NIOSH STELs are 25 ppb for diacetyl and 31 ppb for 2,3-pentanedione [NIOSH 2016]. The NIOSH exposure limits do not differentiate between natural and synthetic chemical origin of diacetyl or 2,3-pentanedione. Although the NIOSH exposure limit for 2,3-pentanedione is above that of diacetyl, 2,3-pentanedione has been shown to be as hazardous as diacetyl [Hubbs et al. 2012; Morgan et al. 2012]. The hazard potential probably increases when these chemicals occur in combination with each other; having exposure to chemicals with the same functional alpha-diketone group and effect on the same system or organ (e.g., lungs) can result in additive effects [ACGIH 2018a]. The NIOSH REL is higher for 2,3-pentanedione than for diacetyl largely because analytic measures were not available in a validated OSHA method to detect 2,3-pentanedione at lower levels. In addition to the REL, NIOSH also recommends an action level for diacetyl of 2.6 ppb to be used with exposure monitoring in an effort to ensure employee exposures are routinely below the diacetyl REL. When exposures exceed the action level, employers should take corrective action (i.e., determine the source of exposure, identify methods for controlling exposure) to ensure that exposures are maintained below the NIOSH REL for diacetyl [NIOSH 2016].

Table 1. Exposure limits for compounds sampled during the NIOSH survey, May 2018

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	-
2,3-Hexanedione	-	-	-	-	-	-
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 limits 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). Typical levels of carbon monoxide in offices are 0–5 ppm. In office settings, carbon dioxide generally should not be greater than 700 ppm above outdoor carbon dioxide levels; this typically corresponds to indoor concentrations below 1200 ppm.

§This is the NIOSH ceiling exposure limit for carbon monoxide. A ceiling concentration should not be exceeded at any time.

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 [Kreiss 2013; Kim et al. 2010; Kanwal et al. 2006]. Obliterative bronchiolitis has also been identified among employees at a coffee roasting and packaging facility that produced unflavored and flavored coffee [CDC 2013b]. 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, 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.

Work-related Asthma

Work-related asthma refers to asthma that is brought on by ("occupational asthma") or made worse by (“work-exacerbated asthma” or “work-aggravated asthma”) workplace exposures [Tarlo 2016; Tarlo and Lemiere 2014; OSHA 2014; Henneberger et al. 2011; NIOSH 2017]. 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.

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; Zuskin et al. 1979, 1985; Thomas et al. 1991]. 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].

Process Description

In May 2018, the coffee roasting, flavoring, and packaging facility employed approximately 20 employees, with approximately five of those employees in production. The employees were not represented by a union. The facility had been at this location since 2001. The facility consisted of three buildings that were approximately 4000 square feet in size. Offices were located in a separate area of one building that also housed the green coffee storage and roast room. A second building housed the grinding, packaging, finished product storage, and shipping and receiving areas. The flavoring area was located in an isolated area of a third building that was shared with another business. An average of 300,000 pounds of coffee was roasted and packaged per year, and approximately 10% of the coffee produced was ground coffee. The facility received green coffee in burlap bags that were stretch-wrapped and stored on pallets until being loaded into silos. Silos with green coffee beans were stored in the green bean storage area until needed for roasting.

To prepare a batch for roasting, a roaster operator weighed the desired amount of green beans before adding them to the roaster. Two roasters were operating during our visit. The small roaster could hold 12 kilograms or approximately 26 pounds of green coffee beans, and the large roaster could hold up to 45 kilogram or approximately 99 pounds of green coffee beans. When ready, the roaster operator dropped the green beans into the roaster. The beans were heated to a specific temperature and for a specific time period for the desired roast. Time and temperature varied among types of roasts. On average, roasts lasted 15 minutes. Occasionally, the roaster operator would pull a small sample of beans from the roaster to check the color of the beans. At the end of each cycle, the roaster operator emptied the roasted beans into a cooling bin where they were agitated by a rotating arm. The cooling bins at both of the roasters used a downdraft exhaust system that pulled air downward past the roasted beans to accelerate cooling. The downdraft systems pulled room air down through the roaster and then out of the building through a ventilation duct and roof exhaust.

The roaster operator monitored the roasting equipment throughout the roasting and cooling process. After cooling, the roasted beans were dispensed from the cooling bin by a pneumatic siphon system through a de-stoner and then dispensed into a large rolling hopper. The roaster operator then manually moved the rolling hoppers to a storage area in the roast room until needed for further processing, including grinding, flavoring, and packaging. The roasters were routinely cleaned to remove accumulated chaff from the exhaust lines. A quality control (QC) technician periodically brewed roasted coffee in a separate quality control room to assess product quality and taste.

Roasted whole bean coffee was transported to the flavoring area in the adjacent building using a bin on wheels. In the flavoring area, the production employee would scoop roasted beans into a small drum mounted on a rotating rack. The attendant would weigh liquid flavorings using a small scale and pour the liquid flavorings into the rotating barrel of roasted coffee beans. After mixing, the attendant would manually empty the beans into storage bins until needed for further processing, including packaging or grinding. Whole bean flavored coffee would then be packaged as flavored whole bean coffee or ground using a grinder in the flavoring area. For grinding flavored coffee, the attendant would use the grinder in the flavoring room to grind approximately five pounds of coffee at a time. Ground flavored coffee was dispensed and packaged in the flavoring room. Packaged flavored whole bean and flavored ground coffee were sent to the shipping area for shipping.

Roasted whole bean coffee was transported to the packaging area in the adjacent building using a bin on wheels. In the packaging area, orders were completed using a weigh/fill machine to hand pack coffee into bags equipped with one-way valves for off-gassing. Two table top grinders were used to grind up to five pounds of unflavored coffee at a time in the hand packaging area. A large grinder was located in the packaging area and could grind up to 300 pounds per hour. After packaging, bags of coffee were stored in the finished goods area in the same building as the packaging area, before shipping out.

A breakroom area, offices, retail space, and cupping lab were located in the same building as the roasting area. Administrative offices were located in two separate locations (upper level and lower level). The non-production areas were separated from the roast room.

Methods

We conducted our visit to the facility during May 1–2, 2018. We held an opening meeting with management and employees, collected air samples, and performed a ventilation assessment. At the conclusion of our site visit, we held a closing meeting with management and employees.

We had the following objectives for the health hazard evaluation:

1. Measure employees' exposure to diacetyl, 2,3-pentanedione, and 2,3-hexanedione during coffee processing;

2. Identify process areas or work tasks associated with emissions of diacetyl, 2,3-pentanedione, and 2,3-hexanedione;
3. Measure levels of CO and CO_2 throughout the facility;
4. Assess ventilation systems and their effect on exposure levels.

Industrial Hygiene Survey

Sampling Times for Alpha-Diketones

We designed the sampling strategy to assess full-shift exposures and identify tasks and processes that were the greatest contributors to worker exposure to alpha-diketones. Sampling was conducted over two days. For diacetyl, 2,3-pentanedione, and 2,3-hexanedione, air samples were collected over seconds, minutes, and hours. Samples collected over minutes can help inform recommendations related to STELs, and those collected over hours can help determine average concentrations that can be compared with the NIOSH RELs for diacetyl and 2,3-pentanedione. These average concentrations might not tell us about short-term peak exposures that could be relevant to respiratory health, particularly when tasks are repeated multiple times per day. Therefore, during particular tasks, we collected personal air samples over several minutes; these samples can provide information about which tasks have relatively higher exposures. To help identify point sources of chemicals, we also performed real-time sampling and collected instantaneous samples over seconds.

Employees who participated in air sampling were given the opportunity to request their individual air sampling results.

Air Sampling and Analysis Using Modified Occupational Safety and Health Administration (OSHA) Methods 1013/1016

We collected personal and area air samples for diacetyl, 2,3-pentanedione, and 2,3-hexanedione on silica gel sorbent tubes on two days during the industrial hygiene survey. The samples were collected and analyzed according to the modified OSHA sampling and analytical Methods 1013/1016 [OSHA 2008; OSHA 2010; LeBouf and Simmons 2017]. 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 TWA concentration from the two samples, assuming that the total 6-hour monitoring results reflected a full work shift (8-hour) TWA exposure. Although this can introduce some error, it is a conservative approach that is 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 the samples were performed in the NIOSH Respiratory Health Division's Organics Laboratory. The samples were extracted for one hour in 95% ethanol:5% water containing 3-pentanone as an internal standard. Samples were analyzed using an Agilent 7890/7001 gas chromatograph/mass spectrometer system operated in selected ion monitoring mode for increased sensitivity compared with the traditional flame ionization detector used in OSHA Methods 1013 and 1016 [LeBouf and Simmons 2017].

A limit of detection (LOD) is the lowest mass an instrument can detect above background and is a criteria used to determine whether to report a result from a sample. The LODs were 0.01 micrograms per sample (µg/sample) for diacetyl, 0.012 µg/sample for 2,3-pentanedione, and 0.02 µg/sample for 2,3-hexanedione. These equate to 0.3 ppb for diacetyl, 0.3 ppb for 2,3-pentanedione, and 0.5 ppb for 2,3-hexanedione for a typical full-shift air sample but varies depending on the volume of air collected during the sampling period. The LODs for task samples are generally higher than typical LOD values for full-shift samples since the air volumes collected during task samples are lower. When the values presented in the report are from samples below the LOD they are denoted by a "<" symbol.

Air Sampling and Analysis Using Evacuated Canisters

We collected instantaneous task-based and source air samples for VOCs including diacetyl, 2,3-pentanedione, and 2,3-hexanedione using evacuated canisters. The evacuated canister sampling setup consisted of a 450-mL evacuated canister equipped with an instantaneous flow controller designed for a short sampling duration (less than 30 seconds). For task-based air samples, a NIOSH employee placed the inlet of the flow controller by the employee's personal breathing zone as they performed their work task to replicate exposure. For source air samples, a NIOSH employee placed the inlet of the flow control directly at the source of interest.

The canister air samples were analyzed using a pre-concentrator/gas chromatograph/mass spectrometer system [NIOSH 2018b], with the addition of acetaldehyde, acetonitrile, and styrene to the list of quantified compounds. The LODs were 0.78 ppb for diacetyl, 1.08 ppb for 2,3-pentanedione, and 1.92 ppb for 2,3-hexanedione based on a three-times dilution factor. However, LODs are dependent on the pressure inside each canister after the samples have been collected, and they can be higher or lower than typical LOD values.

Real-time Air Sampling

We used Tiger VOC detector monitors (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 total VOCs. Areas where higher concentrations of total VOCs are measured help indicate areas where sampling to characterize specific exposures to alpha-diketones might be necessary. We also collected real-time measurements of CO_2, CO, temperature, and relative humidity (RH) using TSI Incorporated (Shoreview, MN) VelociCalc Model 9555-X Multi-Function Ventilation Meters equipped with Model 982 IAQ probes. We continuously measured employee personal exposures to CO and area measurements of CO using a Dräger Pac® 7000 personal single gas detector (Lübeck, Germany). The Dräger Pac® 7000 was placed near the breathing zone of employees and worn by employees while they performed their work duties.

Ventilation Assessment

The size of the ventilation system at the facility combined with limitations of the ventilation measurement equipment we had available precluded us from taking meaningful air flow measurements. However, we were able to measure pressure differentials between adjacent spaces. Differential pressure measurements can indicate what direction air will flow between spaces under different ventilation conditions. Differential pressure measurements between adjacent spaces were taken under various ventilation scenarios using an Energy Conservatory DG-500 Pressure Gauge (Minneapolis, MN).

Statistical Analysis

Industrial Hygiene Survey and Ventilation Assessment

We performed analyses using SAS version 9.4 (SAS Institute, Cary, NC). We created summary statistics by work area location, job title, and task. When the values presented in the report are from samples below the LOD they are denoted by a "<" symbol.

Results

Industrial Hygiene Survey Results

Personal and Area Full-shift Air Sampling Results

OSHA Methods 1013/1016

We collected eight personal and 28 area full-shift air samples over two days (Table A1). None of the full-shift personal samples exceeded the NIOSH RELs of 5 parts per billion for diacetyl or 9.3 parts per billion for 2,3-pentanedione. All samples were below the LOD for 2,3-hexanedione.

NIOSH RELs are intended to be directly compared with personal measurements; therefore, an area air sample that exceeds a NIOSH REL only indicates potential personal exposures. None of the full-shift area samples exceeded the NIOSH RELs for diacetyl or 2,3-pentanedione. The highest full-shift area air concentrations for diacetyl (3.7 ppb) and 2,3-pentanedione (3.3 ppb) were measured near the 5-pound grinder.

Task-Based Air Sampling Results

OSHA Methods 1013/1016

We collected 11 personal task air samples (Tables A2 and A3). Task duration ranged from seven minutes to 33 minutes. We collected personal task air samples while employees flavored coffee (n=1), ground and flavored coffee (n=1), ground coffee (n=1), and roasted coffee (n=8). The highest task-based TWA exposures to diacetyl (14.9 ppb) and third highest task-based TWA exposure to 2,3-pentanedione (12.8 ppb) were measured while an employee ground coffee (Table A2). The second highest task-based TWA exposures to diacetyl (2.9 ppb) and highest task-based TWA exposures to 2,3-pentanedione (13.7 ppb) were observed while an employee flavored roasted coffee. Elevated levels of 2,3-pentanedione were also measured when employees flavored and ground coffee (12.9 ppb). Diacetyl air concentrations measured when employees roasted coffee were as high as 0.7 ppb diacetyl. No detectable amounts of 2,3-pentanedione were measured when employees roasted coffee.

Instantaneous Evacuated Canisters

We collected 19 task-based personal samples near the breathing zone of employees using instantaneous canisters (Table A3). Levels of diacetyl and 2,3-pentanedione observed during certain tasks were similar to the levels described above. The highest instantaneous levels were measured while employees ground coffee. Instantaneous samples taken while employees ground unflavored light roast coffee at the 5-pound grinder ranged from 6.5 ppb to 106 ppb for diacetyl and 5.1 ppb to 76.5 ppb for 2,3-pentanedione. Breathing zone samples taken while employees ground southern pecan flavored coffee in the flavoring area ranged from 7.1 ppb to 9.8 ppb for diacetyl and 5.6 ppb to 6.0 ppb for 2,3-pentanedione. Instantaneous samples taken while employees flavored whole bean coffee or filled 5-pound bags with flavored whole bean coffee with caramel flavor or southern pecan flavor in the flavoring area ranged from less than 0.4 ppb to 2.7 ppb for diacetyl and less than 0.3 ppb to 4.6 ppb for 2,3-pentanedione. An instantaneous sample collected while an employee performed cupping measured 14.1 ppb for diacetyl and 12.9 ppb for 2,3-pentanedione. Sample concentrations collected while employees performed tasks at the roaster or in packaging were lower. Instantaneous breathing zone samples collected while an employee dumped whole roasted beans into the cooling bin were all below the LOD for diacetyl and 2,3-pentanedione. Instantaneous samples collected while an employee packaged whole bean coffee at a weigh/fill machine ranged from < 0.5 ppb to 0.8 ppb diacetyl and were below the LOD for 2,3-pentanedione. The highest level of 2,3-hexanedione (4.3 ppb) was measured at the breathing zone of an employee while grinding five pounds of light roast coffee.

Source Air Sampling Results

Instantaneous Evacuated Canisters

We collected eight source samples for diacetyl and 2,3-pentanedione using evacuated canisters (Table A4). Instantaneous samples were less than 30 seconds in duration. The highest instantaneous source sample for diacetyl (192 ppb), 2,3-pentanedione (168 ppb), and 2,3-hexanedione (4.9 ppb) were measured at the dispenser of the grinder used by an employee in the packaging area, when the grinder was grinding five pounds of light roast coffee. An instantaneous sample taken over the table of cups during the cupping process in the QC room measured 13.6 ppb diacetyl, 13.3 ppb 2,3-pentanedione, and 1.8 ppb 2,3-hexanedione. An instantaneous source sample collected at the weigh-fill machine dispenser opening while the weigh-fill machine was dumping coffee measured 10.9 ppb diacetyl, 7.4 ppb 2,3-pentanedione, and < 0.7 ppb 2,3-hexanedione.

Real-time Monitoring: Carbon Dioxide (CO_2), Carbon Monoxide (CO), and Total Volatile Organic Compounds (VOCs)

A summary of the real-time CO, CO_2, temperature, and total VOC monitoring results can be seen in Table A5. Levels of CO_2 and CO measured at the grinding table with the 5-pound grinder ranged from 371 ppm to 596 ppm for CO_2 and less than 0.1 ppm to 17.8 ppm for CO. Total VOC measurements at the grinding table with the 5-pound grinder ranged from less than 1 ppb to 4973 ppb. The small grinder near the vacuum seal machine in the packaging area had the highest maximum CO measurement of 123 ppm. Levels of CO_2 and CO measured at the roaster operator station ranged from 414 ppm to 793 ppm for CO_2 and less than 0.1 ppm to 2.2 ppm for CO. Total VOC levels ranged from less than 1 ppb to 5106 ppb at the roaster operator station. Area monitoring of the flavoring area measured levels of CO_2 and CO that ranged from 378 ppm to 554 ppm for CO_2 and less than 0.1 ppm to 0.2 ppm for CO. Total VOC measurements in the flavoring area ranged from less than 1 ppb to 1414 ppb. Total VOC measurements in the packaging area near the bag filling station ranged from less than 1 ppb to 1179 ppb.

Levels of CO_2 and CO measured in the administrative office ranged from 397 ppm to 871 ppm for CO_2 and less than 0.1 ppm to 0.6 ppm for CO. Total VOC levels ranged from less than 1 ppb to 5235 ppb in the administrative office. Measurements of CO in the retail area, coffee prep, and serve area ranged from less than 0.1 ppm to 30 ppm. Measurements of CO at the upstairs lunchroom table were low ranging from less than 0.1 ppm to 1 ppm.

Table A6 present a summary of continuous, real-time, personal and area measurements of CO. TWA personal CO measurements ranged from less than 0.1 ppm to 28 ppm and were below the NIOSH REL of 35 ppm for CO exposure.

Ventilation Assessment

Differential pressure measurements taken between two adjacent spaces in the main building demonstrated the production space (the roasting area) was under negative pressure compared with the retail and administrative offices space. The retail area and administrative offices were under positive pressure compared with the roasting area when the roasting downdraft table was either on or off. The positive pressure gradient was also maintained when the air-conditioning system in the retail and administrative offices was turned on or off. The building with the flavoring area also housed another business, and both the flavoring area and the separate business had exhaust fans that could be turned on when air needed to be exhausted from each space. The flavoring area had a bay door that separated it from the adjacent business. All pressure gradient measurements were made with the bay door closed. The flavoring area was under negative pressure when the exhaust fan in the flavoring area and the exhaust fan in the separate business were turned on. The negative pressure gradient was maintained when both fans were turned off. When the exhaust fan in the adjacent business was turned on, but the flavoring area fan was left off, the flavoring area was under positive pressure to the separate business. When the exhaust fan in the flavoring area was turned on, and the exhaust fan in the separate business was turned off, the flavoring area was under negative pressure compared with the separate business.

Discussion

Overall, the highest area samples for total VOCs, CO, diacetyl, and 2,3-pentanedione were observed in areas where roasted coffee was ground. Diacetyl, 2,3-pentanedione, 2,3-hexanedione, other VOCs, and other compounds such as CO_2 and CO are naturally produced when coffee beans are roasted, and grinding the roasted coffee beans produces greater surface area for the off-gassing of these chemicals [Anderson et al. 2003; Akiyama et al. 2003; Daglia et al. 2007; Newton 2002; Nishimura et al. 2003; Raffel and Thompson 2013]. In addition, flavorings added to roasted coffee can contain diacetyl or 2,3-pentanedione. Occupational exposure to diacetyl and 2,3-pentanedione can cause loss of lung function and the lung disease obliterative bronchiolitis [NIOSH 2016]. Some employees developed obliterative bronchiolitis while working at another coffee roasting and packaging facility that used flavorings and had elevated levels of diacetyl and 2,3-pentanedione [CDC 2013; Bailey et al. 2015; Duling et al. 2016].

Alpha-Diketones

Personal Air Sampling

None of the personal full-shift air samples collected on employees who perform various duties inside the facility using standard OSHA methods were above the NIOSH REL for diacetyl or 2,3-pentanedione.

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 risks associated with the levels we measured in May 2018 were acceptable under NIOSH recommendations. As described in the quantitative risk assessment from the NIOSH Criteria Document (Tables 5-27 and 5-34) [NIOSH 2016], after a 45-year working lifetime exposure to 5 ppb (a concentration higher than the highest concentration measured at this facility), NIOSH estimated about 1 in 1,000 workers would develop reduced lung function (FEV_1 below the lower limit of normal). NIOSH predicted that around 1 in 10,000 workers exposed to diacetyl at 5 ppb would develop more severe lung function reduction (FEV_1 below 60% predicted, defined as at least moderately severe by the American Thoracic Society [Pellegrino et al. 2005]). The effects of a working lifetime exposure at 1.3 ppb would be less than those for 5 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 1,000 workers. NIOSH recommends taking steps to reduce diacetyl exposures to below the REL of 5 ppb whenever possible.

Area Air Sampling

We note that NIOSH RELs are intended to be directly compared with personal measurements; therefore, an area air sample that exceeds a NIOSH REL is only an indication of potential personal exposures. All production and administrative areas sampled had full-shift TWA air concentrations that were below the NIOSH REL for diacetyl and 2,3-pentanedione.

Task-Based Exposures

Coffee processing involves multiple tasks that can cause intermittent exposure to diacetyl and 2,3-pentanedione. Traditional full-shift sampling will not characterize these intermittent, peak exposures. Measured short-term peak exposures contribute to average full-shift exposures and can help identify sources and processes that generate diacetyl and 2,3-pentanedione and that can be targeted with engineering controls. Evaluating intermittent and task-based exposures to diacetyl and 2,3-pentanedione is difficult with current validated sampling methods (OSHA Methods 1013/1016). Since tasks are so sporadic in coffee processing, with some only lasting a few seconds or minutes, we used instantaneous evacuated canisters to sample tasks that were only a few seconds to minutes long and OSHA Methods 1013/1016 for longer duration tasks. We sampled by task, with varying durations, to understand which tasks contributed to higher exposures of diacetyl and 2,3-pentanedione.

Tasks with the highest air concentrations of diacetyl or 2,3-pentanedione occurred when employees 1) ground unflavored coffee (14.9 ppb diacetyl; 12.8 ppb 2,3-pentanedione), 2) flavored roasted coffee with southern pecan and caramel flavoring (2.9 ppb diacetyl; 13.7 ppb 2,3-pentanedione), and 3) flavored and ground southern pecan flavored coffee (1.6 ppb diacetyl; 12.9 ppb 2,3-pentanedione. We did not collect bulk samples of liquid flavorings for headspace analysis to determine if diacetyl or 2,3-pentanedione was present in the flavorings used during our survey. We note that differences in liquid flavoring formulations and diacetyl and 2,3-pentanedione content could help explain why samples collected while employees performed flavoring tasks had measured levels of 2,3-pentanedione that were 5 to 8-fold higher than measured levels of diacetyl.

We also measured diacetyl and 2,3-pentanedione using instantaneous sampling, in which sample duration was less than 30 seconds. These instantaneous samples were collected to identify and describe short-duration tasks and point sources of diacetyl and 2,3-pentanedione. The highest instantaneous levels were measured while employees ground coffee (106 ppb diacetyl; 76.5 ppb 2,3-pentanedione). The greater surface area for off-gassing that is produced during grinding could have resulted in the higher air concentrations observed while employees performed flavoring and grinding tasks [Akiyama et al. 2003]. We observed much lower concentrations of diacetyl and 2,3-pentanedione in samples collected while employees ground flavored coffee (range: 7.1 ppb – 9.8 ppb diacetyl; 5.6 ppb – 6.0 ppb 2,3-pentanedione) than when employees ground unflavored coffee. The lower concentrations of diacetyl and 2,3-pentanedione observed while grinding of flavored coffee tasks were performed might be due differences in engineering controls present when grinding flavored or unflavored coffee. Grinding of flavored coffee tasks were isolated in a separate building equipped with a large exhaust fan in the flavoring area that was turned on whenever flavoring and grinding of flavored coffee tasks were performed. The engineering controls present during grinding of flavored coffee likely contributed to reduced air concentrations of diacetyl and 2,3-pentanedione during grinding of flavored coffee.

Source Air Sampling

The highest instantaneous source sample for diacetyl (192 ppb), 2,3-pentanedione (168 ppb), and 2,3-hexanedione (4.9 ppb) was measured at the dispenser of the grinder used by an employee in the packaging area when the grinder was grinding five pounds of light roast coffee.

Real-time Sampling for CO, CO_2, and VOCs

Our real-time monitoring found that the highest overall levels of CO were observed at the packaging grinders. The small grinder near the vacuum seal machine in the packaging area had the highest maximum CO measurement of 123 ppm. None of the personal TWA measurements of CO exceeded the NIOSH REL (35 ppm), NIOSH Ceiling Limit (200 ppm), or OSHA PEL (50 ppm). All CO_2 measurements were below the NIOSH REL (5,000 ppm) and OSHA PEL (5,000 ppm).

Ventilation

Generally, the production area would be expected to have the highest concentrations of airborne contaminants. To keep these contaminants confined to the production area and prevent them from spreading into adjacent areas, the production area should be maintained under negative pressure relative to the adjacent spaces. This would ensure air from the adjacent spaces flows into the production area and not vice versa. The roasting area was maintained under negative pressure relative to the retail area and administrative offices under all conditions tested. Additionally, the flavoring area was maintained under negative pressure relative to the adjacent separate business when the exhaust fan in the flavoring area was on. However, when the exhaust fan in the adjacent business was turned on, but the flavoring area fan was left off, the flavoring area was under positive pressure to the separate business. Constant negative pressure in the production area relative to non-production areas is needed to keep contaminants from the production space from migrating to non-production areas. To maintain consistent negative pressure in the flavoring area, continue to ensure the exhaust fan in the flavoring area is always turned on whenever flavoring tasks are performed in the flavoring area.

Local exhaust ventilation

Local exhaust ventilation systems can capture contaminants when generated and remove contaminants before inhalation by employees can occur. Local exhaust ventilation systems generally consist of hoods or enclosures, duct work, or fans. Depending on the contaminant and whether air is recirculated, filters or other air cleaning technologies can also be incorporated. After properly designed local exhaust ventilation systems are installed, overall workplace exposure levels can be reduced by removing contaminants at the source. The grinders in the packaging area could be modified with local exhaust ventilation that would help reduce overall alpha-diketone concentrations in the facility.

Conclusions

No specific work tasks or job duties resulted in air concentrations of diacetyl and 2,3-pentanedione that exceeded the NIOSH RELs for diacetyl and 2,3-pentanedione. The highest full-shift and task-based diacetyl and 2,3-pentanedione exposure measurements were observed on employees that ground coffee. We observed high instantaneous levels of diacetyl and 2,3-pentanedione during grinding tasks. CO_2 levels were low throughout most of the facility.

During our visit, we found that the production spaces were appropriately under negative pressure relative to non-production spaces when exhaust fans were in operation in production spaces and doors were kept closed between production and non-production spaces. These results could be impacted by day-to-day by variations in the weather, doors or windows being opened or closed, or operating states (on vs. off) of various ventilation systems.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage this coffee roasting, flavoring, and packaging facility to use a labor-management health and safety committee or working group to discuss our recommendations and develop an action plan. Our recommendations are based on an approach known as the hierarchy of controls. This approach groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees.

Engineering Controls

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

1. Ensure the exhaust fan in the flavoring area is always turned on whenever flavoring tasks are performed to maintain consistent negative pressure in the flavoring area.
2. Continue to keep all doors between the production space and non-production space closed at all times.
3. Consult with a ventilation engineer to install local exhaust ventilation at the 5-pound and 300-pound packaging grinders to reduce air concentrations of alpha-diketones (diacetyl and 2,3-pentanedione), and carbon monoxide during grinding of coffee. Relocating the grinders to an exterior wall might make implementation of engineering controls easier.

Administrative Controls

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

1. Whenever possible, employees should avoid spending time in the immediate area where coffee is being ground or ground coffee is being packaged.
2. Whenever possible, cover bins of roasted whole beans and ground coffee to aid in reducing the overall emission of alpha-diketones and other chemicals including CO and CO_2, into the workplace. Specifically, ensure that whenever possible, hoppers filled with ground coffee are kept covered.
3. To reduce exposures to VOCs (including alpha-diketones) and CO, minimize

production tasks that require employees to place their heads directly above or inside the roasted bean bins.

4. Continue to periodically clean the roaster's exhaust according to manufacturer instructions, including removing chaff build-up to reduce a fire hazard and improve the efficiency, energy usage, and roaster performance.
5. Ensure employees understand potential hazards (e.g., diacetyl, 2,3-pentanedione, CO, CO_2, dust) in the workplace and how to protect themselves. OSHA's *Hazard Communication Standard*, also known as the "*Right to Know Law*" [29 CFR 1910.1200] requires that employees are informed and trained on potential work hazards and associated safe practices, procedures, and protective measures.
6. Ensure employees are educated to consider the risks of further exposure if they develop lower respiratory symptoms (e.g., cough, shortness of breath, wheezing) that are progressive and severe in degree. Employees should report new, persistent, or worsening respiratory symptoms to their personal healthcare providers and to a designated individual at this workplace. Employees with new, persistent, or worsening respiratory symptoms should share this report with their healthcare providers.

Personal Protective Equipment

The effectiveness of respiratory protection as personal protective equipment depends on avoiding breakdowns in implementation that can cause insufficient protection from respiratory exposures. Proper use of respiratory protection (respirators) requires 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, respirators fit users, respirators are maintained in good working order, and respirators are worn when needed. Supporting programs such as training, change-out schedules, and medical assessment might be 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.

1. Ensure N95 disposable filtering-face piece respirators are available for voluntary use for protection against green or roasted coffee dust exposure such as when emptying burlap bags of green beans, cleaning the roaster exhaust system of chaff, emptying the chaff containers, or cleaning the green bean storage area. N95 respirators should be available in various sizes, and each potential N95 user should receive a copy of Appendix D of the OSHA Respiratory Protection Standard (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=9784). Information about Appendix D and voluntary use of respirators can be found on the OSHA website at

   https://www.osha.gov/video/respiratory_protection/voluntaryuse_transcript.html

   Please be aware that N95s are not protective against alpha-diketones (diacetyl, 2,3-pentanedione, or 2,3-hexanedione). In cases of dual exposure to dust and alpha-diketones, NIOSH-certified organic vapor cartridges (for the alpha-diketones) and particulate cartridges/filters (for the dust) would be warranted.

Medical Monitoring

The purpose of a medical monitoring program is to help assure the health of employees who have workplace exposures to health hazards (e.g., diacetyl, 2,3-pentanedione) known to pose risk for potentially serious health conditions or illnesses (e.g., obliterative bronchiolitis, asthma).

1. Because this facility flavors coffee, the NIOSH Criteria document [NIOSH 2016] recommends that the employer institute a medical monitoring program for all employees who work in or enter areas where coffee is flavored. Employees who work in or enter these areas for 40 or more hours per year should be included in the medical monitoring program.
2. According to the NIOSH Criteria document [NIOSH 2016], employees should have baseline evaluations before they are allowed to work in the flavoring area where they might be exposed to diacetyl, 2,3-pentanedione, or similar flavoring compounds. Employees in the medical monitoring program should be evaluated with a questionnaire (to obtain health and work task information) and spirometry (to assess lung function) every six months caused by the potentially rapid development of lung disease. If an employee is identified as having lung disease from exposure to diacetyl, 2,3-pentanedione, or a similar flavoring compound, then all employees who perform similar job tasks or have a similar or greater potential for exposure should be evaluated every three months [NIOSH 2016].

Smoking Cessation Program

In a workplace with risk of occupational lung disease, prevention of smoking-related lung disease is important and makes the detection of work-related adverse effects easier. If employees smoke, we recommend implementing a smoking cessation program to assist employees to stop smoking. The Centers for Disease Control and Prevention offers tools and resources for setting up a smoking cessation program [CDC 2017].

Appendix A: Tables

Table A1. Time-weighted average OSHA Method 1013/1016 full-shift personal and area air sampling results by location, NIOSH survey, May 2018

Analyte	Sample Type	Location*	N	Above LOD N (%)	Minimum Concentration (ppb)	Maximum Concentration (ppb)	Above REL N
Diacetyl	Personal	Production and Administrative	1	1 (100%)	0.4	0.4	0
Diacetyl	Personal	Packaging and Flavoring	3	3 (100%)	0.4	1.3	0
Diacetyl	Personal	Retail Area	2	0 (0%)	<0.3	<0.3	0
Diacetyl	Personal	Roasting	2	1 (50%)	<0.3	0.8	0
Diacetyl	Area	Administration	2	1 (50%)	<0.3	1.9	N/A
Diacetyl	Area	Breakroom	2	0 (0%)	<0.3	<0.3	N/A
Diacetyl	Area	Finished Product Storage	2	1 (50%)	<0.3	1.5	N/A
Diacetyl	Area	Flavoring Room	2	1 (50%)	<0.3	0.4	N/A
Diacetyl	Area	Green Bean Storage	2	1 (50%)	<0.3	0.4	N/A
Diacetyl	Area	Grinding table with 5 pound grinder	2	2 (100%)	0.6	1.8	N/A
Diacetyl	Area	Small grinder near vacuum seal machine in packaging area	2	2 (100%)	2.3	3.7	N/A
Diacetyl	Area	Packaging	4	4 (100%)	0.9	2.1	N/A
Diacetyl	Area	QC Lab	2	2 (100%)	0.4	2.3	N/A
Diacetyl	Area	Repair Area	2	0 (0%)	<0.3	<0.3	N/A
Diacetyl	Area	Retail Shop	4	2 (50%)	<0.3	0.8	N/A
Diacetyl	Area	Roasting	2	1 (50%)	<0.3	0.5	N/A
2,3-Pentanedione	Personal	Production and Administrative	1	0 (0%)	<0.3	<0.3	0
2,3-Pentanedione	Personal	Packaging and Flavoring	3	3 (100%)	0.5	1.6	0
2,3-Pentanedione	Personal	Retail Area	2	1 (50%)	<0.3	0.4	0
2,3-Pentanedione	Personal	Roasting	2	2 (100%)	0.4	0.9	0
2,3-Pentanedione	Area	Administration	2	1 (50%)	<0.3	2.2	N/A
2,3-Pentanedione	Area	Breakroom	2	0 (0%)	<0.3	<0.3	N/A
2,3-Pentanedione	Area	Finished Product Storage	2	1 (50%)	<0.3	1.4	N/A
2,3-Pentanedione	Area	Flavoring Room	2	1 (50%)	<0.3	1.1	N/A
2,3-Pentanedione	Area	Green Bean Storage	2	1 (50%)	<0.3	0.4	N/A

Table A1 (continued). Time-weighted average OSHA Method 1013/1016 full-shift personal and area air sampling results by location, NIOSH survey, May 2018

Analyte	Sample Type	Location*	N	Above LOD N (%)	Minimum Concentration (ppb)	Maximum Concentration (ppb)	Above REL N
2,3-Pentanedione	Area	Grinding table with 5-pound grinder	2	2 (100%)	0.6	1.4	N/A
2,3-Pentanedione	Area	Small grinder near vacuum seal machine in packaging area	2	2 (100%)	2.0	3.3	N/A
2,3-Pentanedione	Area	Packaging	4	4 (100%)	0.8	2.0	N/A
2,3-Pentanedione	Area	QC Lab	2	2 (100%)	0.4	2.5	N/A
2,3-Pentanedione	Area	Repair Area	2	0 (0%)	<0.3	<0.3	N/A
2,3-Pentanedione	Area	Retail Shop	4	3 (75%)	<0.3	0.9	N/A
2,3-Pentanedione	Area	Roasting	2	2 (100%)	0.4	0.5	N/A
2,3-Hexanedione	Personal	Production and Administrative	1	0 (0%)	<0.5	<0.5	-
2,3-Hexanedione	Personal	Packaging and Flavoring	3	0 (0%)	<0.5	<0.5	-
2,3-Hexanedione	Personal	Retail Area	2	0 (0%)	<0.5	<0.5	-
2,3-Hexanedione	Personal	Roasting	2	0 (0%)	<0.5	<0.5	-
2,3-Hexanedione	Area	Administration	2	0 (0%)	<0.5	<0.5	N/A
2,3-Hexanedione	Area	Breakroom	2	0 (0%)	<0.5	<0.5	N/A
2,3-Hexanedione	Area	Finished Product Storage	2	0 (0%)	<0.5	<0.5	N/A
2,3-Hexanedione	Area	Flavoring Room	2	0 (0%)	<0.5	<0.5	N/A
2,3-Hexanedione	Area	Green Bean Storage	2	0 (0%)	<0.5	<0.5	N/A
2,3-Hexanedione	Area	Grinding table with 5-pound grinder	2	2 (0%)	<0.5	<0.5	N/A
2,3-Hexanedione	Area	Small grinder near vacuum seal machine in packaging area	2	2 (0%)	<0.5	<0.5	N/A
2,3-Hexanedione	Area	Packaging	4	0 (0%)	<0.5	<0.5	N/A
2,3-Hexanedione	Area	QC Lab	2	0 (0%)	<0.5	<0.5	N/A
2,3-Hexanedione	Area	Repair Area	2	0 (0%)	<0.5	<0.5	N/A
2,3-Hexanedione	Area	Retail Shop	4	0 (0%)	<0.5	<0.5	N/A
2,3-Hexanedione	Area	Roasting	2	0 (0%)	<0.5	<0.5	N/A

Note: OSHA=Occupational Safety and Health Administration; 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); < indicates below the 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 area samples; "–"indicates that there is currently no REL for 2,3-hexanedione; "Production Area" location includes employees that were cross-trained and performed tasks at different areas.

Table A2. Summary of short-term OSHA Method 1013/1016 personal air sampling results by task, NIOSH survey, May 2018

Analyte	Task	N	Above LOD N (%)	Minimum Concentration (ppb)	Maximum Concentration (ppb)	Mean (range) Sample Duration (minutes)
Diacetyl	Flavor coffee (southern pecan and caramel flavors)	1	1 (100%)	2.9	2.9	16
Diacetyl	Flavor and grind coffee beans (southern pecan flavor)	1	1 (100%)	1.6	1.6	13
Diacetyl	Grind coffee beans	1	1 (100%)	14.9	14.9	7
Diacetyl	Roast coffee beans	8	1 (13%)	< 0.4	0.7	18 (9–33)
2,3-Pentanedione	Flavor coffee	1	1 (100%)	13.7	13.7	16
2,3-Pentanedione	Flavor and grind coffee beans	1	1 (100%)	12.9	12.9	13
2,3-Pentanedione	Grind coffee beans	1	1 (100%)	12.8	12.8	7
2,3-Pentanedione	Roast coffee beans	8	0 (0%)	< 0.4	< 1.6	18 (9–33)
2,3-Hexanedione	Flavor coffee	1	0 (0%)	< 1.3	< 1.3	16
2,3-Hexanedione	Flavor and grind coffee beans	1	0 (0%)	< 1.6	< 1.6	13
2,3-Hexanedione	Grind coffee beans	1	0 (0%)	< 2.9	< 2.9	7
2,3-Hexanedione	Roast coffee beans	8	0 (0%)	< 0.6	< 2.4	18 (9–33)

Note: OSHA=Occupational Safety and Health Administration; 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); < indicates below the LOD.

Table A3. Instantaneous evacuated canister method* air sampling results by task, NIOSH survey, May 2018

Task Description	Diacetyl (ppb)	2,3-Pentanedione (ppb)	2,3-Hexanedione (ppb)
Dropping beans into cooling bin	<0.4	<0.3	1.2
Dumping light roast beans from roaster into cooling bin	<0.5	<0.3	1.2
Flavoring – dumping flavored whole bean (southern pecan)	0.9	<0.3	<0.8
Flavoring – filling 5 pound bags with whole bean flavored coffee (southern pecan)	<0.4	<0.3	<0.6
Flavoring whole bean coffee with caramel flavor	2.7	4.6	<0.8
Flavoring whole bean coffee with caramel flavor	1.0	2.8	<1.0
Flavoring whole bean coffee southern pecan flavor	<0.6	<0.4	1.3
Grinding decaf coffee 5 pound bag	14.1	8.3	1.0
Grinding flavored coffee (southern pecan)	9.8	6.0	0.9
Grinding flavored coffee (southern pecan)	7.1	5.6	0.9
Grinding coffee 5 pounds	15.2	10.0	1.2
Grinding coffee 5 pounds	4.7	2.9	<0.8
Grinding light roast 5 pounds	6.5	5.1	1.0
Grinding light roast 5 pounds	106	76.5	4.3
Grinding light roast 5 pounds	20.6	18.4	<0.8
Packaging whole bean coffee at weigh/fill machine	<0.5	<0.3	<0.8
Packaging whole bean coffee at weigh/fill machine	0.8	<0.5	<1.2
Packaging whole bean coffee at weigh/fill machine	<0.6	<0.4	1.3
Quality control - cupping	14.1	12.9	1.7

Note: NIOSH=National Institute for Occupational Safety and Health; ppb=parts per billion; < indicates below the limit of detection.
***Sampling duration approximately 30 seconds; task-based air samples were collected by placing the inlet of the canister sampler in the employee's personal breathing zone as he/she performed work task.**

Table A4. Instantaneous evacuated canister method* air sampling results by source, NIOSH survey, May 2018

Source Description	Diacetyl (ppb)	2,3-Pentanedione (ppb)	2,3-Hexanedione (ppb)
At grinder opening discharge; grinding light roast, 5 pounds	64.3	61.7	1.9
At grinder opening discharge; grinding light roast, 5 pounds	192	168	4.9
At packaging label machine	4.1	2.7	<1.1
At weigh/fill machine dispenser opening while dumping coffee	10.9	7.4	<0.7
Taken above cooling bin with light roast	1.6	<0.3	1.0
Taken above flavoring mixer bin filled with flavored whole bean coffee	<0.4	<0.3	<0.7
Taken above storage bin as destoner dumped light roast beans into a bin on scale	3.9	4.7	1.2
Taken over table of cups during cupping process in QC room	13.6	13.3	1.8

Note: NIOSH=National Institute for Occupational Safety and Health; ppb=parts per billion; < indicates below the limit of detection.
***Sampling duration was approximately 30 seconds; source air samples were collected by placing the inlet of the canister sampler near roasted beans.**

Table A5. Summary of continuous area air monitoring results for carbon dioxide, carbon monoxide, and total volatile organic compounds, NIOSH industrial hygiene survey, May 2018

Location, Day of Survey	CO_2 (ppm) Mean (Range)	CO (ppm) Mean (Range)	Total VOC (ppb) Mean (Range)
Grinding table with 5 pound grinder, Day 1	408 (373 — 596)	0.7 (<0.1 — 17.8)	72 (< 1 — 4973)
Grinding table with 5 pound grinder, Day 2	412 (371 — 582)	1.0 (<0.1 — 10.4)	207 (32 — 292)
Packaging Area, Bag Filling Station, Day 2	—	—	30 (< 1 — 1179)
Roaster Operator Station, Day 1	460 (414 — 793)	0.1 (<0.1 — 2.2)	29 (< 1 — 5106)
Roaster Operator Station, Day 2	453 (421 — 629)	0.04 (<0.1 — 0.7)	13.6 (< 1 — 192)
Flavoring Area, Day	—	—	44 (< 1 — 1414)
Flavoring Area, Day 2	405 (378 — 554)	0.0003 (<0.1 — 0.2)	136 (4 — 478)
Administrative Office, Day 1	605 (397 — 871)	0.04 (<0.1 — 0.6)	344 (< 1 — 5,235)
Retail Shop, Coffee Prep and Serving Area, Day 1	—	—	8 (< 1 — 49)
Retail Area, Coffee Prep/Serve Area	—	0.13 (<0.1 — 30)	—
Upstairs Lunchroom Table	—	0.01 (<0.1 — 1)	—
Small Grinder near Vacuum Seal Machine in Packaging Area	—	0.01 (<0.1 — 123)	—

Note: NIOSH=National Institute for Occupational Safety and Health; CO_2=carbon dioxide; CO=carbon monoxide; VOC=volatile organic compounds ppm=parts per million; ppb=parts per billion;; "-" indicates the measurement was not recorded.

Table A6. Summary of continuous air measurements for carbon monoxide, NIOSH industrial hygiene survey, May 2018

Type of Sample	Job Title	Work Area	CO (ppm) Mean (range)
Personal	Roaster	Roasting Area	0.02 (<0.1 – 5)
Personal	Roaster	Roasting Area	0.03 (<0.1 – 6)
Personal	Production	Packaging	0.09 (<0.1 – 14)
Personal	Production	Packaging	0.36 (<0.1 – 28)
Personal	Production	All over	0.05 (<0.1 – 9)
Personal	Production	Packaging	0.06 (<0.1 – 6)
Personal	Administrative	Retail Area	0.02 (<0.1 – 2)

Note: NIOSH=National Institute for Occupational Safety and Health; CO=carbon monoxide; ppm=parts per million; < indicates below the limit of detection for the instrument used to detect carbon monoxide.

References

ACGIH (American Conference of Governmental Industrial Hygienist) [2018a]. 2017 TLVs® and BEIs®: Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ACGIH [2018b]. Chemicals Substances and Other Issues Under Study (TLV®-CS) [http://www.acgih.org/tlv-bei-guidelines/documentation-publications-and-data/under-study-list/chemical-substances-and-other-issues-under-study-tlv]. Date accessed: March 2019.

Akiyama M, Murakami K, Ohtani N, Iwatsuki K, Sotoyama K, Wada A, Tokuno K, Iwabuchi H, Tanaka K [2003]. Analysis of volatile compounds released during the grinding of roasted coffee beans using solid-phase microextraction. J Agric Food Chem *51*(7):1961-1969.

Anderson BA, Shimoni E, Liardon R, Labuza P [2003]. The diffusion kinetics of carbon dioxide in fresh roasted and ground coffee. J Food Eng *59*:71-78.

Bailey RL, Cox-Ganser JM, Duling MG, LeBouf RF, Martin SB Jr, Bledsoe TA, Green BJ, Kreiss K [2015]. Respiratory morbidity in a coffee processing workplace with sentinel obliterative bronchiolitis cases. Am J Ind Med *58*(12):1235-1245.

CDC (Centers for Disease Control and Prevention) [2013a]. Carbon monoxide [https://www.cdc.gov/niosh/topics/co-comp/default.html]. Date accessed: March 2019.

CDC [2013b]. Obliterative bronchiolitis in workers in a coffee-processing facility—Texas, 2008–2012. Morb Mortal Wkly Rep *62*(16):305–307.

CDC [2017]. Smoking & tobacco use: quit smoking [https://www.cdc.gov/tobacco/quit_smoking/index.htm]. Date accessed: March 2019.

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

Daglia M, Papetti A, Aceti C, Sordelli B, Spini V, Gazzani G [2007]. Isolation and determination of α-dicarbonyl compounds by RP-HPLC-DAD in green and roasted coffee. J Agric and Food Chem *55*(22):8877-8882.

Day G, LeBouf R, Grote A, Pendergrass S, Cummings K, Kreiss K, and Kullman G [2011]. Identification and measurement of diacetyl substitutes in dry bakery mix production. J Occ Env Hygiene *8*(2):93-103.

Duling MG, LeBouf RF, Cox-Ganser JM, Kreiss K, Martin SB Jr, Bailey RL [2016]. Environmental characterization of a coffee processing workplace with obliterative bronchiolitis in former workers. J Occup Environ Hyg *13*(10):770-781.

Figley KD, Rawling FF [1950] Castor bean: an industrial hazard as a contaminant of green coffee dust and used burlap bags. J Allergy *21*:545–553.

Hawley B, Cox-Ganser JM, Cummings KJ [2017]. Carbon monoxide exposure in workplaces, including coffee processing facilities. J Respir Crit Care Med *196*(8):1080-1081.

Henneberger PK, Redlich CA, Callahan DB, Harber P, Lemière C, Martin J, Tarlo SM, Vandenplas O, Torén K; ATS Ad Hoc Committee on Work-Exacerbated Asthma [2011]. An official American Thoracic Society statement: work-exacerbated asthma. Am J Respir Crit Care Med *184*(3):368–378.

Hubbs AF, Cumpston AM, Goldsmith WT, Battelli LA, Kashon ML, Jackson MC, Frazer DG, Fedan JS, Goravanahally MP, Castranova V, Kreiss K, Willard PA, Friend S, Schwegler-Berry D, Fluharty KL, Sriram K [2012]. Respiratory and olfactory cytotoxicity of inhaled 2,3-pentanedione in Sprague-Dawley rats. Am J Pathol *181*(3):829-844.

Kanwal R, Kullman G, Piacitelli C, Boylstein R, Sahakian N, Martin S, Fedan K, Kreiss K [2006]. Evaluation of flavorings-related lung disease risk at six microwave popcorn plants. J Occup Environ Med. *48*(2):149-57.

Karr RM, Davies RJ, Butcher BT, Lehrer SB, Wilson MR, Dharmarajan V, Salvaggio JE [1978]. Occupational asthma. J Allergy Clin Immunol *61*(1):54–65.

Kim TJ, Materna BL, Prudhomme JC, Fedan KB, Enright PL, Sahakian NM, Windham GC, Kreiss K [2010]. Industry-wide medical surveillance of California flavor manufacturing workers: Cross-sectional results. Am J Ind Med *53*(9):857-865.

Kreiss K [2013]. Occupational causes of constrictive bronchiolitis. Curr Opin Allergy Clin Immunol *13*(2):167-172.

Langford NJ [2005]. Carbon dioxide poisoning. Toxicol Rev *24*(4):229-235.

LeBouf RF and Simmons M [2017]. Increased sensitivity of OSHA method analysis of diacetyl and 2,3-pentanedione in air. J Occup Environ Hyg *14*(5):343-348.

Morgan DL, Jokinen MP, Price HC, Gwinn WM, Palmer SM, Flake GP [2012]. Bronchial and bronchiolar fibrosis in rats exposed to 2,3-pentanedione vapors: implications for bronchiolitis obliterans in humans. Toxicol Pathol *40*(3):448-465.

Morgan DL, Jokinen MP, Johnson CL, Price HC, Gwinn WM, Bousquet RW, Flake GP [2016]. Chemical reactivity and respiratory toxicity of the α-diketone flavoring agents: 2,3-butanedione, 2,3-pentanedione, and 2,3-hexanedione. Toxicol Pathol *44*(5):763–783.

Newton J [2002]. Carbon monoxide exposure from coffee roasting. Appl Occup Environ Hyg *17*(9):600-602.

NIOSH [2016]. NIOSH pocket guide to chemical hazards. [http://www.cdc.gov/niosh/npg/]. Date accessed: March 2019.

NIOSH [2017]. Work-related asthma [https://www.cdc.gov/niosh/topics/asthma/default.html]. Date accessed: February 2019.

NIOSH [2012]. Flavoring-related lung disease. Information for healthcare providers. Department of Health and Human Services, Centers for Disease Control and Prevention, DHHS (NIOSH) Publication No. 2012-148 (supersedes 2012-107) [http://www.cdc.gov/niosh/docs/2012-148/]. Date accessed: March 2019.

NIOSH [2016]. Criteria for a recommended standard: occupational exposure to diacetyl and 2,3-pentanedione. 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. 2016-111. [https://www.cdc.gov/niosh/docs/2016-111/]. Date accessed: March 2019.

Nishimura F, Abe S, Fukunaga T [2003]. Carbon monoxide poisoning from industrial coffee extraction. JAMA *290*(3):334.

Oldenburg M, Bittner C, Baur X [2009]. Health risks due to coffee dust. Chest *136*(2):536-544.

OSHA (Occupational Safety and Health Administration) [1993]. Compliance and enforcement activities affected by the PELs decision. August 5, 1993 Memorandum. [https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=21220]. Date accessed: March 2019.

OSHA [2003]. Enforcement policy for respiratory hazards not covered by OSHA permissible exposure limits. January 24, 2003 Memorandum. [https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=24749]. Date accessed: March 2019.

OSHA [2008]. Sampling and analytical methods: Method 1013 – Acetoin and diacetyl [http://www.osha.gov/dts/sltc/methods/validated/1013/1013.html]. Date accessed: March 2019.

OSHA [2010]. Sampling and analytical methods: Method 1016 – 2,3-pentanedione [http://www.osha.gov/dts/sltc/methods/validated/1016/1016.html]. Date accessed: March 2019.
OSHA [2014]. OSHA Fact sheet: Do you have work-related asthma? A guide for you and your doctor. Washington, D.C.: U.S. Department of Labor, Occupational Safety and Health Administration [https://www.osha.gov/Publications/OSHA3707.pdf]. Date accessed: March 2019.

OSHA [2018]. Permissible exposure limits – annotated tables [https://www.osha.gov/dsg/annotated-pels/index.html]. Date accessed: March 2019.

Pellegrino R, Viegi G, Brusasco V, Crapo RO, Burgos F, Casaburi R, Coates A, van der Grinten CP, Gustafsson P, Hankinson J, Jensen R, Johnson DC, MacIntyre N, McKay R, Miller MR, Navajas D, Pedersen OF, Wanger J [2005]. Interpretative strategies for lung function tests. Eur Respir J *26*(5):948–968.

Raffel JB, Thompson J [2013]. Carbon monoxide from domestic coffee roasting: a case report. Ann Intern Med *159*(11):795-796.

Rose JJ, Wang L, Xu Q, McTiernan CF, Shiva S, Tejero J, Gladwin MT [2017]. Carbon monoxide poisoning: pathogenesis, management, and future directions of therapy. Am J Respir Crit Care Med *195*(5):596-606.

Tarlo SM, Lemiere C [2014]. Occupational asthma. N Engl J Med *370*:640-649.

Tarlo SM [2016]. Update on work-exacerbated asthma. Int J Occup Med Environ Health *29*(3):369-374.

Thomas KE, Trigg CJ, Baxter PJ, Topping M, Lacey J, Crook B, Whitehead P, Bennett JB, Davies RJ [1991]. Factors relating to the development of respiratory symptoms in coffee process workers. Br J Ind Med *48*(5):314–322.

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Availability of Report

Copies of this report have been sent to the employer and employees at the facility. The state health department and the Occupational Safety and Health Administration Regional Office have also received a copy.

This report is available at https://www.cdc.gov/niosh/hhe/reports/pdfs/2018-0071-3342.pdf.

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