Coffee and Flavoring Related Health Hazard Evaluations

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Outline

- Obliterative bronchiolitis
- Microwave popcorn industry
- Diacetyl
- Flavored food products
- 2,3-Pentanedione (diacetyl substitute)
- Flavoring-related health hazard evaluations
- NIOSH recommended exposure limits for diacetyl and 2,3-pentanedione
- Coffee roasting and packaging facilities
- Next steps

The New England Journal of Medicine

CLINICAL BRONCHIOLITIS OBLITERANS IN WORKERS AT A MICROWAVE-POPCORN PLANT

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ABSTRACT

Background In May 2000, eight persons who had formerly worked at a microwave-popcorn production plant were reported to have severe bronchiolitis obliterans. No recognized cause was identified in the plant. Therefore, we medically evaluated current employees and assessed their occupational exposures.

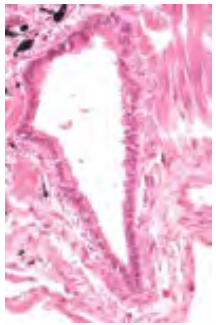
Methods Questionnaire responses and spirometric findings in participating workers were compared with data from the third National Health and Nutrition Examination Survey, after adjustment for age and smoking status. We evaluated the relation between expo-

IN May 2000, eight persons who had formerly worked at a plant that produces microwave popcorn were reported to the Missouri Department of Health to have bronchiolitis obliterans.[1,2] These workers had become ill during the period from 1993 to 2000, while employed at the popcorn plant, and none had reported an incident of presumed overexposure that preceded their symptoms. Four had worked in the room where microwave-popcorn flavoring agents were mixed, and four had worked only in the microwave-popcorn packaging areas. On the basis

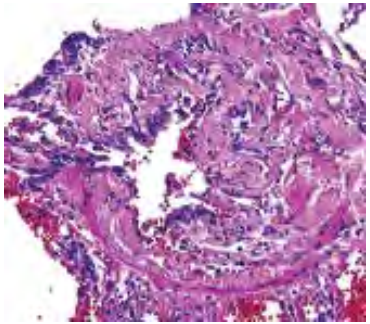
Kreiss et al. [2002]. N Engl J Med *347*(5):330-338.

Obliterative Bronchiolitis

- Cough, shortness of breath on exertion, and sometimes wheezing
- Scarring of smallest airways (bronchioles)



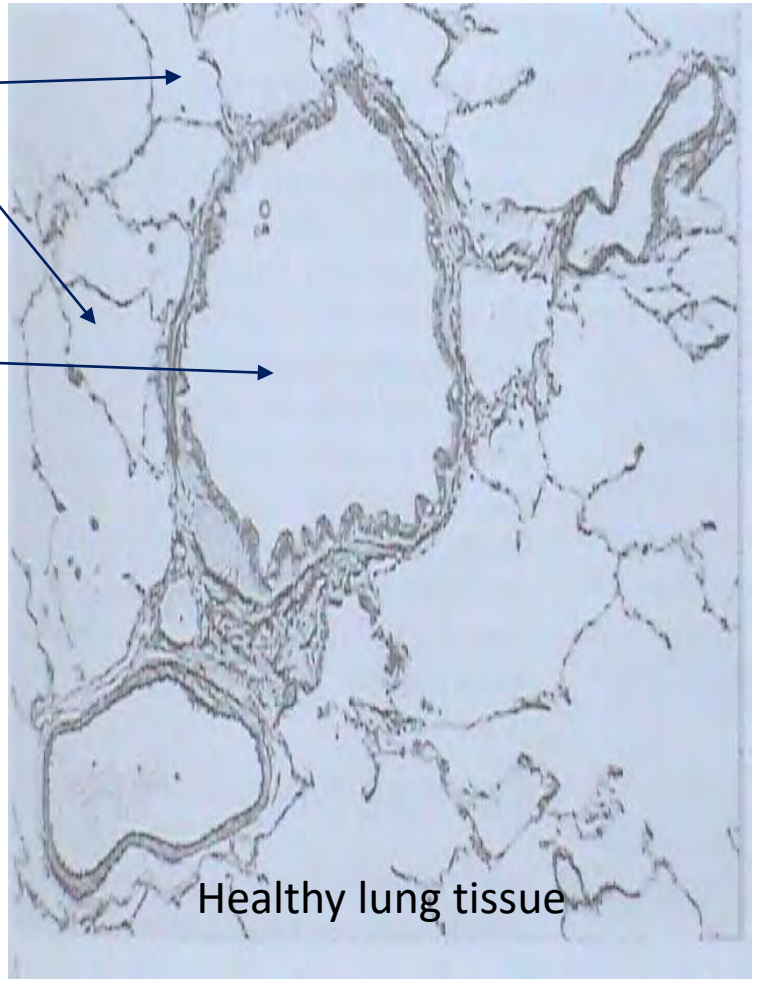
Healthy bronchiole

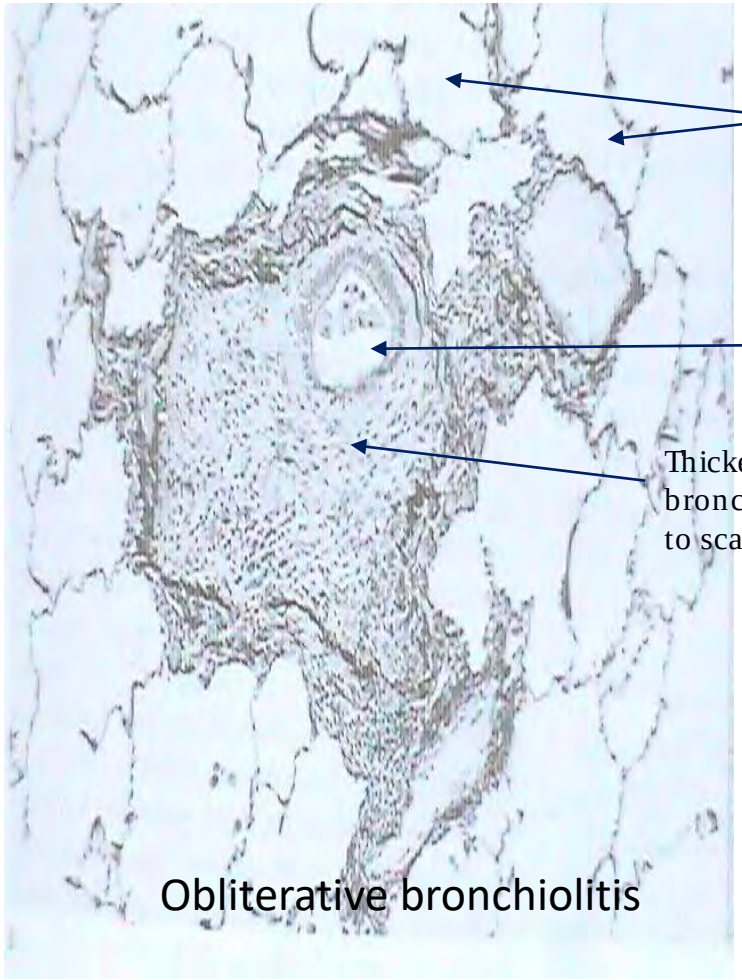


Bronchiole of affected worker

- Fixed airways obstruction on spirometry common but a mixed or restrictive pattern also found, compatible with air trapping
- Normal diffusing capacity (DLCO)

NIOSH [2012]. DHHS (NIOSH) Publication No. 2015-148.

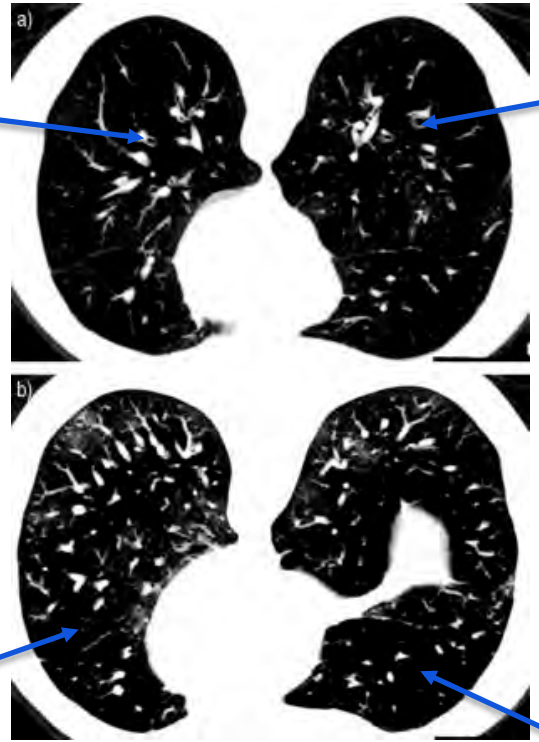

Alveoli
(air sacs)
Bronchiole
Healthy lung tissue


Alveoli
(air sacs)
Small airway
lumen
Thickened
bronchiole wall due
to scar tissue
Obliterative bronchiolitis

High Resolution Computed Tomography

Inspiratory view

Expiratory view



Dilated bronchiole (small airway)

Dilated Bronchiole (small airway)

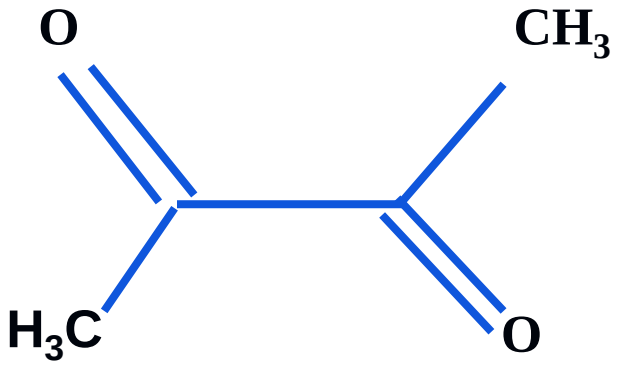
Air trapping

Air trapping

Butter Flavoring Vapors at Microwave Popcorn Plant

Diacetyl

- Alpha-diketone
- Imparts buttery taste
- Found naturally in foods
- Also can be added to foods



Microwave Popcorn Industry

JOEM • Volume 48, Number 2, February 2006

CME Available for this Article at ACOEM.org

Evaluation of Flavorings-Related Lung Disease Risk at Six Microwave Popcorn Plants

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Nancy Sahakian, MD, MPH
Stephen Martin, MS
Kathleen Fedan, BS
Kathleen Kreiss, MD

Learning Objectives

- Explain how the concentration of diacetyl, an airborne butter-flavoring chemical, relates to the specific type of work performed by employees at plants producing microwave popcorn.
- Relate the level and duration of exposure to butter-flavoring chemicals such as diacetyl, as well as smoking history, to respiratory tract symptoms, airway dysfunction, and lung biopsy findings of bronchiolitis.
- Describe practical measures that may decrease exposure to butter-flavoring chemicals and forestall or prevent the development of respiratory tract disease.

Since August 2000, National Institute for Occupational Safety and Health (NIOSH) staff have investigated the occurrence of fixed obstructive lung disease consistent with constrictive bronchiolitis obliterans in microwave popcorn workers exposed to airborne butter-flavoring chemicals. A NIOSH cross-sectional medical and environmental survey at plant A (the index plant) revealed an elevated prevalence of obstructive lung disease that was associated with cumulative exposure to diacetyl, the predominant butter-flavoring chemical in the air of the plant.[1,2] In experiments conducted at NIOSH, rats exposed to vapors from a butter flavoring used at this plant devel-

Kanwal et al. [2006]. JOEM *48*(2):149-157.

CDC

MMWR™

Morbidity and Mortality Weekly Report

Weekly April 27, 2007 / Vol. 56 / No. 16

Workers' Memorial Day — April 28, 2007

Workers' Memorial Day, April 28, was established to recognize workers who died or were injured on the job. On average, nearly 16 workers in the United States die each day from injuries sustained at work (*1*), and 134 die from work-related diseases (*2*). Daily, an estimated 11,500 private-sector workers have a nonfatal work-related

Fixed Obstructive Lung Disease Among Workers in the Flavor-Manufacturing Industry — California, 2004–2007

Bronchiolitis obliterans, a rare and life-threatening form of fixed obstructive lung disease, is known to be caused by exposure to noxious gases in occupational settings and has been described in workers in the microwave-popcorn industry who

CDC [2007]. Morb Mortal Wkly Rep *56*(16):389-393.

Flavoring Manufacturing

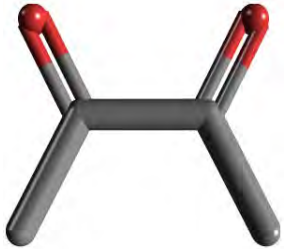
- Development and production of flavoring chemicals for food and beverages
- Hundreds of chemical exposures
- Recognized risk of obliterative bronchiolitis from diacetyl
- Respiratory toxicity of most other flavoring chemicals is unknown

Flavored Food Products

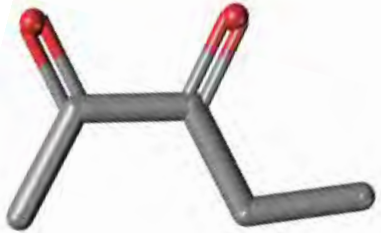
- Snack foods
  - Microwave popcorn, cookies, soft spreads, chips, crackers
- Bakery products – cake mixes
- Flour
- Margarines
- Dairy products
  - Cheese and yogurt
- Soft drinks
- Coffee

Diacetyl Subtitute

Diacetyl (2,3butanedione)



2,3-Pentanedione (acetyl propionyl)



Hubbs et al. [2012]. Am J Pathol *181*(3):229-844.

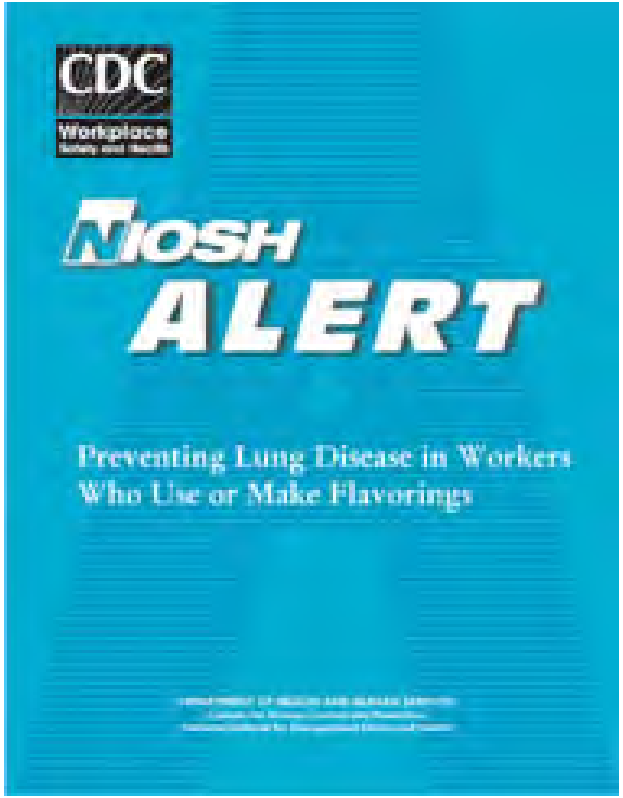
Food Manufacturing in United States

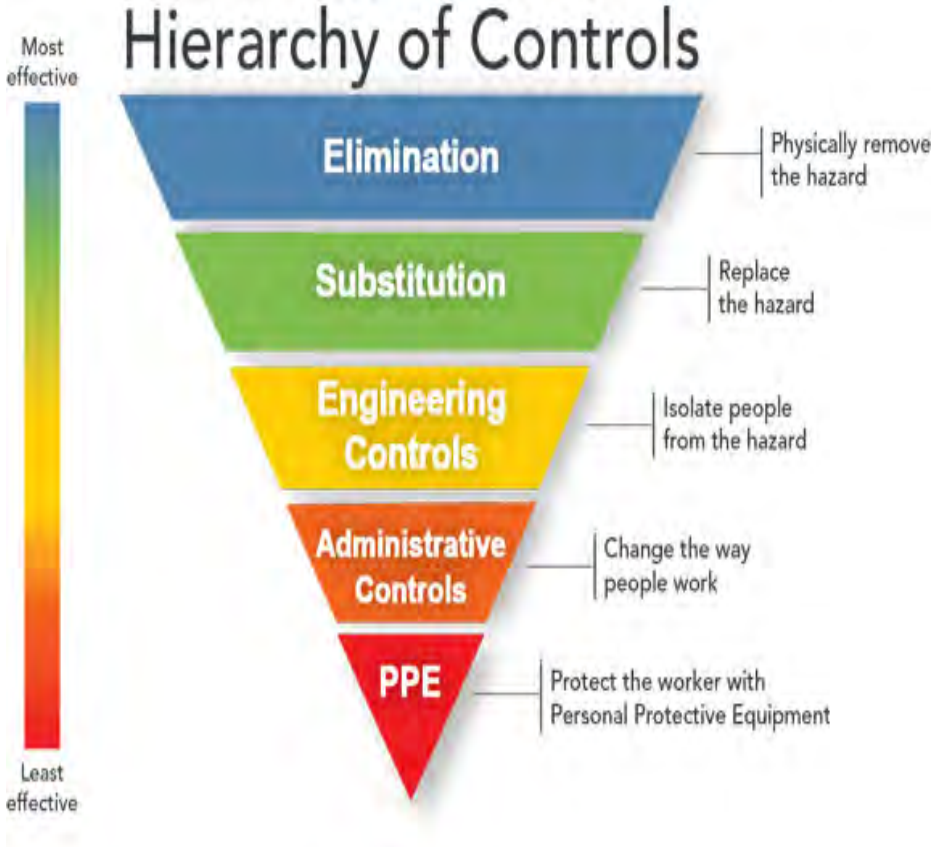
Industry	NAICS Code	May 2018
Food manufacturing	311	1.6 million
Bakeries and tortilla manufacturing	3118	312,350
Other food manufacturing	3119	224,020
Dairy product manufacturing	3115	145,530
Sugar and confectionery product manufacturing	3113	76,570
Coffee and teamanufacturing	311920	22,309 (2017)*†
Beverage industry	3121	250,863 (2017) *†

Source: May 2018 National Industry-Specific Occupational Employment and Wage Estimates (https://www.bls.gov/oes/current/oessrci.htm#31-33)
*Quarterly Census of Employment and Wages 2017 (https://www.bls.gov/cew/datatoc.htm)
†Annual average of monthly employment levels for 2017

Flavoring-Related Health Hazard Evaluations

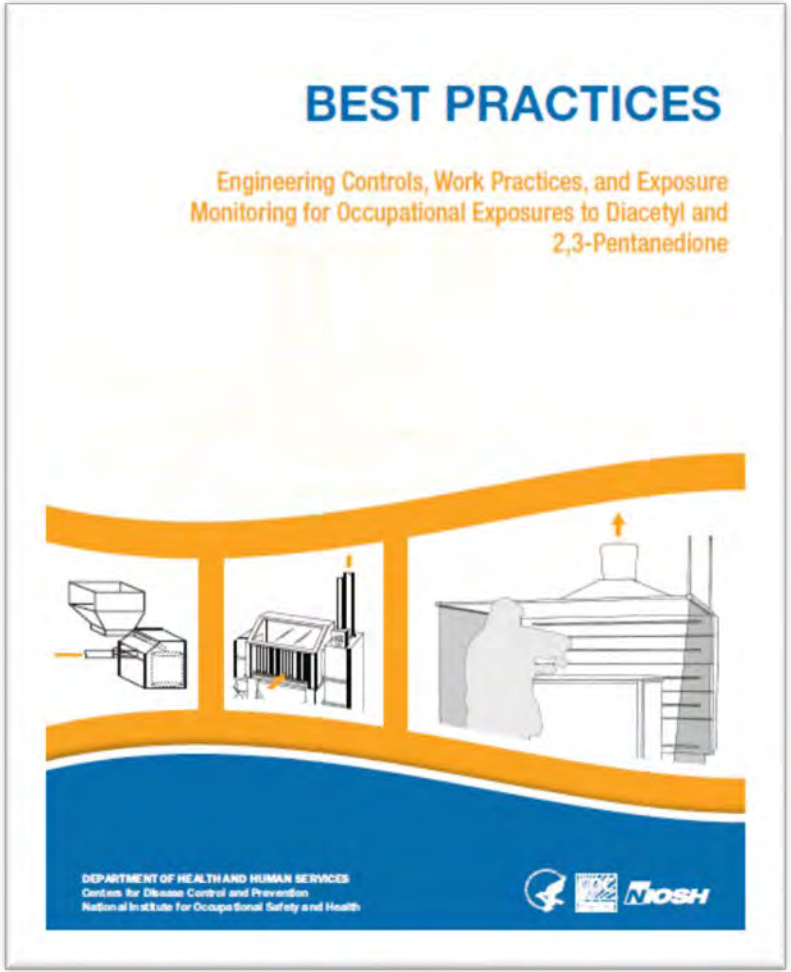
- Microwave popcorn
- Flavoring manufacture
- Snack food production (potato chips, corn chips)
- Cream cheese manufacture
- Bakery mix production
- Pet food manufacture
- Commercial kitchens
- Coffee roasting and packaging facilities





NIOSH [2003]. DHHS (NIOSH) Publication No. 2004-110.

https://www.cdc.gov/niosh/topics/hierarchy



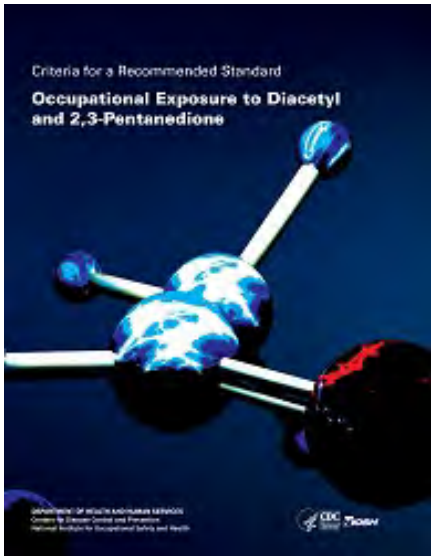
NIOSH [2015]. DHHS (NIOSH) Publication No. 2015-197.

NIOSH Recommended Exposure Limits

- DHHS (NIOSH) Publication Number 2016-111

- 8-hour time-weighted average recommended exposure limit (REL)
  - 5 parts per billion (ppb) for diacetyl
  - 9.3 ppb for 2,3-pentanedione

- 15-minute short-term exposure limit (STEL)
  - 25 ppb for diacetyl
  - 31 ppb for 2,3-pentanedione



NIOSH [2016]. DHHS (NIOSH) Publication No. 2016-111.

American Conference of Governmental Industrial Hygienists (ACGIH®) Threshold Limit Values (TLVs®)

- 8-hour time-weighted average threshold limit (TLV-TWA)
  - 10 parts per billion (ppb) for diacetyl
  - 9.3 ppb for 2,3-pentanedione
- 15-minute short-term threshold limit (TLV-STEL)
  - 25 ppb for diacetyl
  - 31 ppb for 2,3-pentanedione
- No recommended exposure limits for 2,3-pentanedione

Morbidity and Mortality Weekly Report

Obliterative Bronchiolitis in Workers in a Coffee-Processing Facility — Texas, 2008–2012

Obliterative bronchiolitis, a rare, irreversible form of fixed obstructive lung disease, has been identified in workers exposed to flavoring chemicals while working in the microwave-popcorn and flavoring-manufacturing industries (*1*); the occupational risk to workers outside these industries is largely unknown. This report describes two cases of obliterative bronchiolitis identified in workers employed in a small coffee-processing facility. Both patients' illness was misdiagnosed before they received a diagnosis of work-related obliterative bronchiolitis, which had not been identified previously in the coffee-processing industry. These cases reinforce the need for exposure evaluation in all industries in which work-

clearance therapy improved her cough, her dyspnea continued to worsen; an open lung biopsy was performed, which revealed constrictive bronchiolitis (the histopathologic correlate of obliterative bronchiolitis) with both narrowed and obliterated airways with surrounding fibrous tissue and a variable mixed chronic inflammatory cell infiltrate. Based on this result, she received a diagnosis of obliterative bronchiolitis.

At the patient's most recent evaluation in April 2012, she continued to describe symptoms of severe shortness of breath with even light exertion, paroxysmal cough, and an inability to tolerate smells. Lung function testing at that time showed

CDC [2013]. Morb Mortal Wkly Rep *62*(16):305-307.

Coffee Processing Facility

- Diacetyl and 2,3-pentanedione detected throughout facility
  - Highest concentrations in flavoring room and area where unflavored coffee ground and packaged
- Associations between flavoring chemical exposures and shortness of breath on exertion and obstruction
- Investigations in 24 coffee roasting and packaging facilities (18 closed; 6 open)

Bailey et al. [2015]. Am J Ind Med *58*(12):1235-1245.
Duling et al. [2016]. J Occup Environ Hyg *13*(10):770-781.

Sources of Diacetyl and 2,3-Pentandione

- Naturally produced and released during the coffee roasting process (Maillard reaction)

- Grinding roasted coffee produces greater surface area for off-gassing
- Storing roasted coffee in hoppers to off-gas before packaging
- Flavoring chemicals added to roasted coffee beans
  - A case of obliterative bronchiolitis identified in a current worker at facility that flavored coffee

NIOSH [2019]. DHHS (NIOSH) Publication No. 2016-0164.

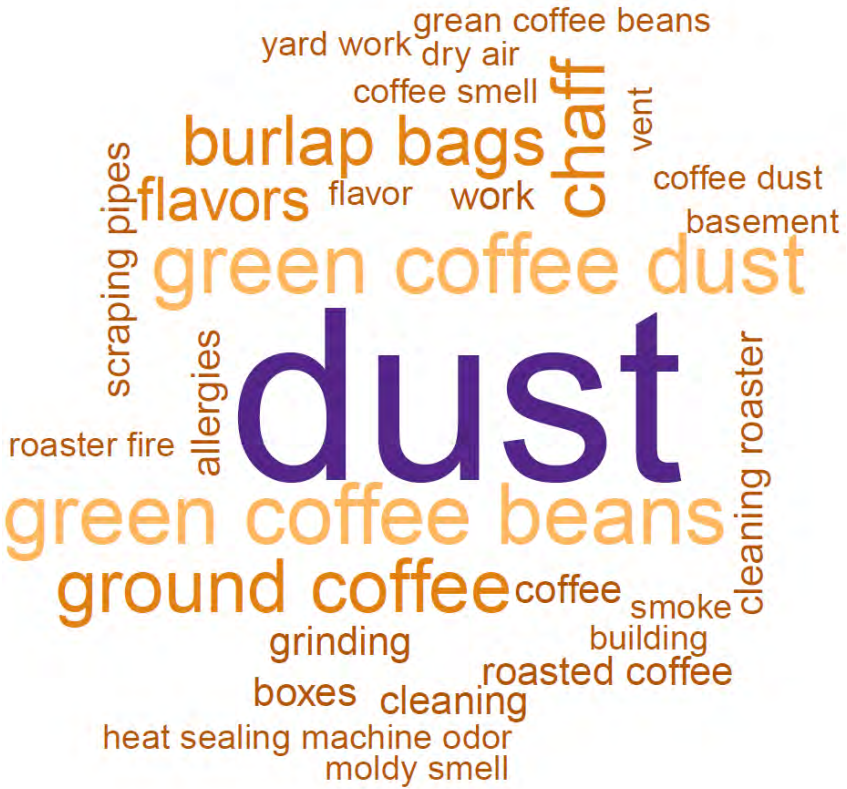
Carbon Monoxide and Carbon Dioxide

- During roasting, coffee beans also generate carbon dioxide (CO_2) carbon monoxide (CO)
- Grinding increases the release of these gases.
- High exposures to CO or CO_2 can cause headache, dizziness, fatigue, nausea, confusion, rapid breathing, impaired consciousness, coma, or death

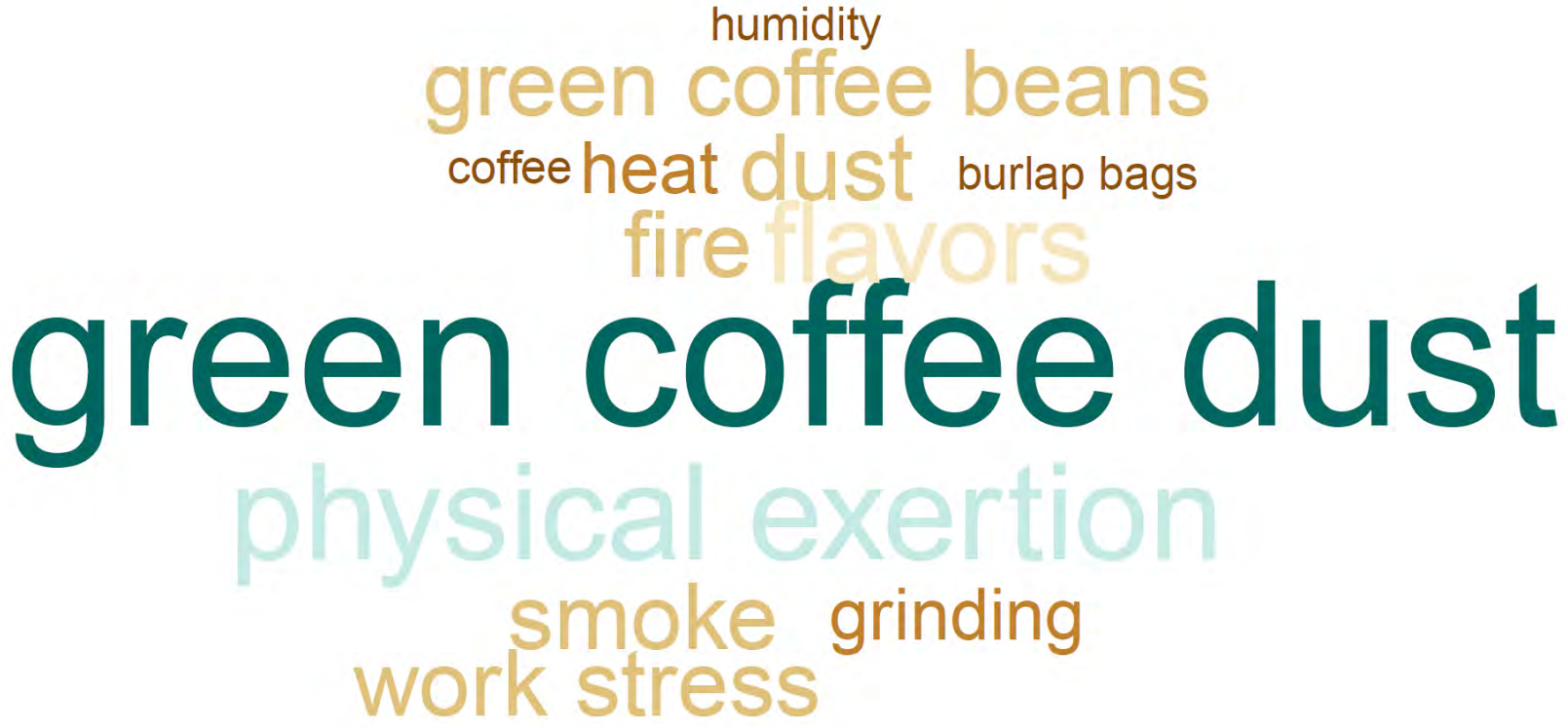
Reported Symptoms

- Upper respiratory and eye symptoms commonly reported with work-related pattern
- Asthma-like symptoms also frequently reported with work-related pattern
- Coffee industry known for risk of occupational asthma in relation to green and roasted coffee allergens and castor bean allergens

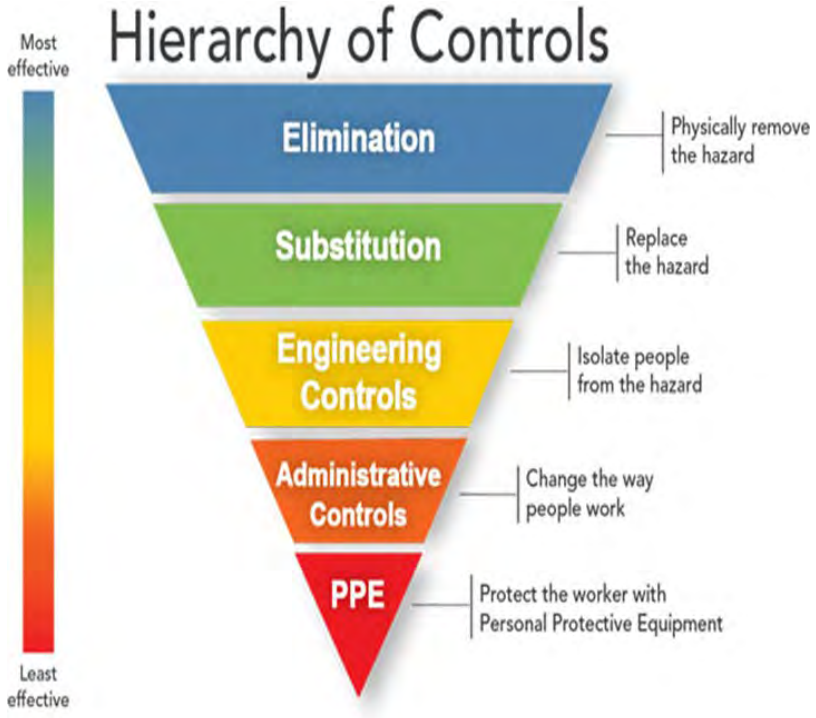
Caused or Aggravated Upper Respiratory Symptoms



Caused or Aggravated Lower Respiratory Symptoms

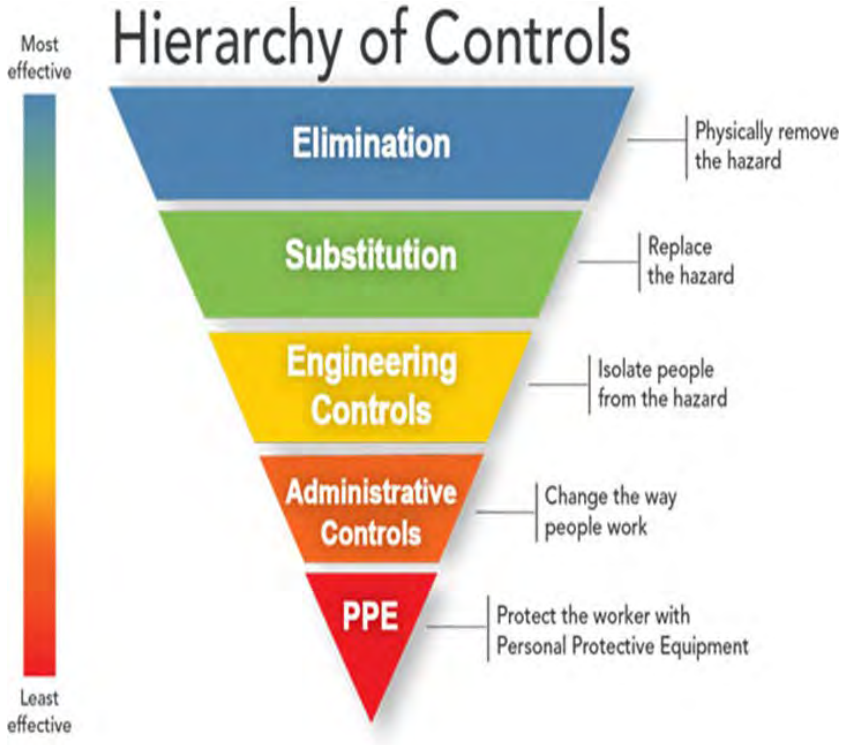


Reducing Employee Exposures



- Control emissions at the source (grinding machines and flavoring stations)
- Local exhaust ventilation and enclosures in grinding and flavoring areas to separate employees from roasted coffee or flavoring sources
- Cover containers of roasted coffee to reduce the overall emission of alpha-diketones and other chemicals (e.g., CO, CO_2)

Reducing Employee Exposures



- Roasted coffee beans should not be blended by hand; use automatic mechanism
- Employee education on potential hazards (diacetyl, 2,3-pentanedione, CO, CO_2, green bean and roasted coffee dust) in the workplace and how to protect themselves
- Respiratory protection

Table 2. The effects of diacetyl exposure level and exposure length on lung function (values abstracted from NIOSH 2016, Tables 5-27 and 5-29).

	Excess prevalence of lung impairment (per thousand)					
	FEV_1 < LLN	< 60% of predicted FEV_1	FEV_1 < LLN	< 60% of predicted FEV_1	FEV_1 < LLN	< 60% of predicted FEV_1
Diacetyl (ppb)	2.5 years exposure		10 years exposure		45 years exposure	
50	0.5	0.1	2.6	0.3	12.3	1.2
20	0.2	0.1	1.1	0.1	4.8	0.5
10	0.2	0.1	0.4	0.0	2.5	0.2
5	0.1	0.1	0.2	0.0	1.3	0.1
2	0.1	0.0	0.2	0.0	0.4	0.0
1	0.1	0.0	0.1	0.0	0.2	0.0

Note: FEV_1: forced expiratory volume in one second; LLN: lower limit of normal; ppb: parts per billion.

NIOSH [2016]. DHHS (NIOSH) Publication No. 2016-111.

NIOSH-Issued Publications

Criteria for a Recommended Standard: Occupational Exposure to Diacetyl and 2,3-Pentanedione

Publication Types

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Criteria for a Recommended Standard: Occupational Exposure to Diacetyl and 2,3-Pentanedione

DHHS (NIOSH) Publication Number 2016–111 October 2016

Diacetyl and its substitute, 2,3-pentanedione, are widely used as flavoring compounds. The National Institute for Occupational Safety and Health (NIOSH) objective in establishing recommended exposure limits (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.

In this Criteria Document, NIOSH reviews the scientific literature concerning potential health effects, toxicology, and risk assessment pertaining to diacetyl and 2,3-pentanedione. Recommendations are provided on engineering controls, work practices, and personal protective equipment to prevent and control workplace exposures to diacetyl and 2,3-pentanedione.

This Criteria Document is contained in PDF files, for ease of handling. The following table of contents allows you to open or download individual sections or the entire Criteria Document:

https://www.cdc.gov/niosh/docs/2016-111/default.html.

The Challenge of the Small Airways

- Symptomatic disease without objective abnormalities on non-invasive testing
  - Standard tests are insensitive
  - More sensitive non-invasive tests needed

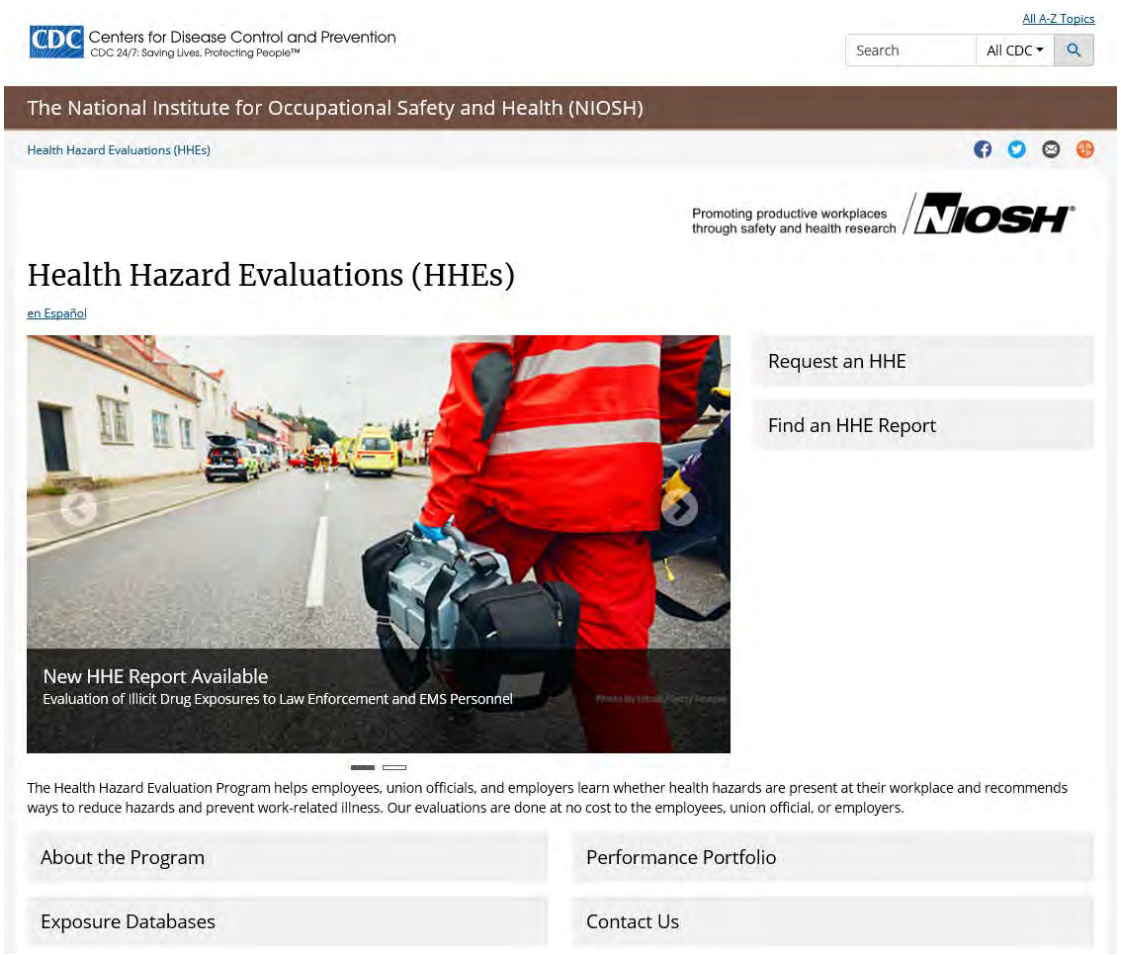
- Asymptomatic disease with physiologic or radiographic abnormalities
  - Detected through workplace surveillance
  - Opportunity for secondary prevention

Cummings & Kreiss [2015]. Semin Respir Crit Care Med *36*(3):366-378.

Next Steps

- Aggregating health and air sampling data collected in NIOSH health hazard evaluations to improve understanding of respiratory health risks in the coffee roasting and packaging industry

- Evaluating efficacy of engineering controls in reducing exposures to diacetyl and 2,3-pentanedione during coffee processing activities



https://www.cdc.gov/niosh/hhe/default.html

Promoting productive workplaces through safety and health research NIOSH

FLAVORINGS–RELATED LUNG DISEASE

Coffee Roasting and Packaging Facilities

Coffee roasting and packaging facilities vary in size, number of employees and shifts, and the amount of coffee they roast, grind, and package. Some facilities are more automated than others, and some have attached or associated cafés. However, in general, coffee roasting and packaging facilities have many common processes.

- Green coffee beans are delivered to the facility (often in jute or burlap bags) and stored or emptied into containers such as hoppers until roasted.
- Before roasting, the green coffee beans are cleaned to remove stones, wood, and other impurities.
- Many facilities blend coffee beans before roasting or after the roasting process. Blending involves mixing different types of coffee beans for a specific taste.
- After roasting, the coffee beans are cooled. To make ground coffee, there is a grinding step. The roasted product is then allowed to off-gas.

https://www.cdc.gov/niosh/topics/flavorings/processing.html

Acknowledgements

- **NIOSH**
  - Brie Hawley Blackley
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  - R. Reid Harvey
  - Ryan LeBouf
  - Steve Martin
  - Tia McClelland
  - Randall (Randy) Nett
  - Anand Ranpara
  - Marcia Stanton
  - Brian Tift
  - M. Abbas Virgi
  - Kristin Cummings (now with the Occupational Health Branch, California Department of Public Health)
  - Many more

- **NIOSH medical and industrial hygiene survey teams**

- **Health hazard evaluation participants**

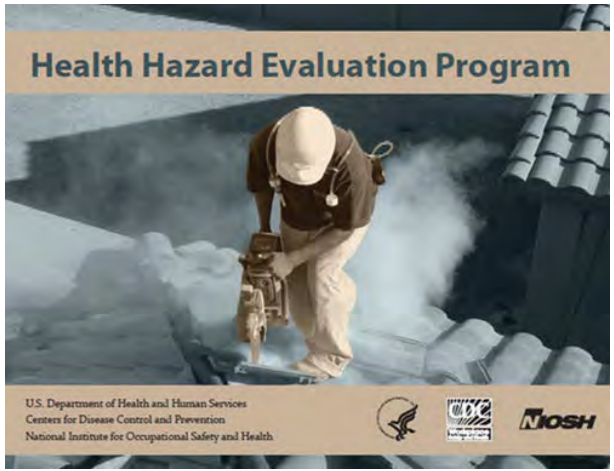
NIOSH Webpage Links

- Health Hazard Evaluation Program: https://www.cdc.gov/niosh/hhe/default.html
- Flavoring-Related Lung Disease: https://www.cdc.gov/niosh/topics/flavorings/default.html
- Flavoring-Related Lung Disease: Information for Healthcare Providers: https://www.cdc.gov/niosh/docs/2012-148/
- NIOSH Alert: Preventing Lung Disease in Workers or Use or Make Flavorings: https://www.cdc.gov/niosh/docs/2004-110/
- Best Practices: Engineering Controls, Work Practices and Exposure Monitoring for Occupational Exposures to Diacetyl and 2,3-Pentanedione: https://www.cdc.gov/niosh/topics/flavorings/additional.html
- Coffee Roasting and Packaging Facilities: https://www.cdc.gov/niosh/topics/flavorings/processing.html
- Criteria for Recommended Standard: Occupational Exposure to Diacetyl and 2,3-Pentanedione: https://www.cdc.gov/niosh/docket/archive/docket245.html

For more information, contact CDC
1-800-CDC-INFO (232-4636)
TTY: 1-888-232-6348 www.cdc.gov

NIOSH Health Hazard Evaluation Program

- Worksite investigation in response to a request from employees, employers, unions, or government agencies
- Determine whether harmful exposures, processes, or conditions exist or cause injuries or illnesses
- Provide recommendations



https://www.cdc.gov/niosh/hhe/default.html

Health Hazard Evaluation Requests

- Who can request a Health Hazard Evaluation?
  - Three current employees when more than three employees at place of employment
  - One current employee if three or fewer employee as place of employment
  - Union
  - Management
- Technical assistance requests
  - Other government agencies
  - Local, state health departments

Obliterative Bronchiolitis
Other Occupational Exposures

- Sulfur mustard gas (chemical weapon)
- World Trade Center disaster
- Fiberglass-reinforced plastics (resin, styrene, others)

Weinberger et al. [2011]. Pulm Pharmacol Ther *24*(1)92-99.
Tang & Loke [2012]. Crit Rev Toxicol *42*(8):688-702.
Mann et al. [2005]. Am J Ind Med *48*(3)225-229.
Cullinan et al. [2013]. Occup Environ Med *70*(5):357-359.
Chen et al. [2013]. Occup Environ Med *70*(9):675-676.
Cummings & Kreiss [2015]. Semin Respir Crit Care Med *36*(3):366-378.

Coffee Cafés

- No cases of obliterative bronchiolitis have been reported in coffee café workers as of September 2019.

- Exposures of café workers to diacetyl and 2,3-pentanedione are likely very different from production workers in coffee roasting and packaging facilities.

- The amount of coffee ground in cafés is typically smaller than in industrial size coffee roasting and packaging facilities.

Coffee Cafés

- Café employees should not place their faces right in front of or right above freshly ground coffee.

- To prevent buildup of contaminants in the air, we recommend that coffee cafés do not recirculate 100 percent of air from café spaces without bringing in any outdoor air.

- If cafés are co-located with a roasting and packaging facility, the café's ventilation system should not recirculate air from the production spaces.

https://www.cdc.gov/niosh/topics/flavorings/qa.html

Table 1. Occupational exposure limits for dust, carbon monoxide, carbon dioxide, diacetyl, and 2,3-pentanedione

Compound	NIOSH				ACGIH		OSHA	
	REL	STEL	Ceiling Limit	IDLH	TLV	STEL	PEL	STEL
Total dust	-	-	-	-	-	-	15 mg/m^3	-
Respirable dust	-	-	-	-	3.0 mg/m3*	-	5.0 mg/m^3	-
Inhalable dust	-	-	-	-	10 mg/m3*	-	-	-
Carbon monoxide	35 ppm	-	200 ppm	1,200 ppm	25 ppm	-	50 ppm	-
Carbon dioxide	5,000 ppm	30,000 ppm	-	40,000 ppm	5,000 ppm	30,000 ppm	5,000 ppm	-
Diacetyl	5.0 ppb	25 ppb	-	-	10 ppb	20 ppb	-	-
2,3-Pentanedione	9.3 ppb	31 ppb	-	-	-	-	-	-

Note: NIOSH=National Institute for Occupational Safety and Health; ACGIH=American Conference of Governmental Industrial Hygienist; OSHA=Occupational Safety and Health Administration; REL=recommended exposure limit; STEL=short-term exposure limit; IDLH=immediately dangerous to life or health; TLV=threshold limit value; PEL=permissible exposure limit; mg/m^3=milligram per cubic meter; ppb=parts per billion; ppm=parts per million; "-"=no exposure limit available.

*ACGIH does not have TLVs for inhalable or respirable dust but does provide guidelines; ACGIH guidelines recommend airborne concentrations for respirable dust be kept below 3 mg/m^3 and inhalable dust be kept below 10 mg/mg^3.

https://www.cdc.gov/niosh/topics/flavorings/limits.html