Diacetyl

Exposures & Controls

By Lori Schroth

IN BRIEF

- **Diacetyl is a chemical used in microwave popcorn and flavoring production plants to enhance the flavors of the manufactured products.**
- **Diacetyl exposure has been linked to the development of bronchiolitis obliterans, an irreversible lung disease.**
- **Regulatory guidance and various research studies were analyzed to identify where government agencies stand on regulating diacetyl and what the future holds.**
- **This article explores the background, health effects, regulatory guidance and control measures for diacetyl and diacetyl substitutes.**

Diacetyl (2,3-butanedione) is a chemical used to add flavor and aroma to food and other products. Diacetyl and its substitutes are commonly manufactured in microwave popcorn and flavoring production plants, and they also are used in the making of beverages, snack foods, baked goods, prepared canned and frozen foods, and candy (OSHA, 2010a, b). Food and Drug Administration (FDA, 2011) classifies diacetyl and its substitutes as "generally recognized as safe (GRAS)."

While the substance may be safe to consume, that does not mean it is safe to work around. Through extensive research and case studies, NIOSH has found that diacetyl is a standard air contaminant in the popcorn and flavoring industry (OSHA, 2010a, b). Numerous jobs may expose workers to diacetyl, including mixing, weighing, pouring, transferring or other handling activities, as well as during cleaning and maintenance operations, quality assurance and laboratory work (OSHA, 2010a, b).

In May 2000, numerous workers at a microwave popcorn processing facility displayed similar respiratory symptoms and, ultimately, developed bronchiolitis obliterans (OSHA, 2011a, b, c). Since bronchiolitis obliterans is an uncommon lung disease, the local health department (Missouri Department of Health and Senior Services) launched an investigation and requested NIOSH's assistance. NIOSH (2003a, b; 2006) linked the development of bronchiolitis obliterans to occupational exposure to diacetyl. Bronchiolitis obliterans became known as popcorn workers' lung due to the correlation of the disease with the butter flavoring of microwave popcorn (Kanwal & Kullman, 2007; NIOSH, 2003a, b). Many lawsuits from popcorn and flavoring plant workers, as well as regulatory concerns, soon followed.

NIOSH's investigations sparked OSHA's interest. The agency added microwave popcorn processing plants to its national emphasis program (NEP) in 2007 (OSHA, 2007a, b; 2011a, b, c). OSHA launched this program to address controls required to reduce and eliminate occupational exposure to diacetyl. In addition, OSHA (2007a, b) added the industry to the targeted inspection list and offered compliance assistance to processing plants.

Health Effects & Treatment

OSHA Administrator David Michaels stated, "It is alarming that workers continue to be at risk of dying from exposure to diacetyl and diacetyl substitutes. Illnesses and death from these chemicals are preventable" (OSHA, 2011c). Inhalation of and physical contact with diacetyl can result in many health effects; contact can lead to eye, nose, throat and skin irritation (NIOSH, 2003a, b). NIOSH's investigation at a flavoring plant revealed a high rate of reports correlated with diacetyl exposure–about 50% of all workers experienced nasal irritation; nearly 50% of office and warehouse workers, as well as 80% of production and laboratory workers, had eye irritation; and 36% of production workers experienced skin problems (Kanwal & Kullman, 2007).

Inhaling diacetyl can result in fatigue, fever, night sweats and weight loss, as well as respiratory effects such as cough, difficulty breathing and occupational asthma (Kreiss, 2002; NIOSH, 2003a, b). In 2008, a study conducted by National Institute of Environmental Health Sciences determined that both acute and chronic exposures to diacetyl result in damage to the nose lining, throat irritation and airway inflammation (OSHA, 2010a, b). These signs of illness usually do not improve when the worker is no longer exposed to the diacetyl (OSHA, 2011a, b, c).

Symptoms appear slowly and steadily, but can quickly become more severe. Exposure to diacetyl also can cause permanent lung damage and lung disease, such as bronchiolitis obliterans (Kreiss, 2002). Severe lung damage and disease can ultimately lead to serious disability and even death.

Respiratory illnesses associated with diacetyl can easily be mistaken as other illnesses. To correctly diagnose symptoms thought to be diacetyl-induced, a medical professional asks the patient a list of symp-

Lori Schroth, CSP, is a safety and occupational health professional at Concurrent Technologies Corp. in Johnstown, PA. She holds a B.S. in Safety Sciences and a B.S. in Natural Sciences from Indiana University of Pennsylvania. She is pursuing an M.S. in Occupational Safety, Health and Environmental Management at Columbia Southern University. Schroth is a member of ASSE's Western Pennsylvania Chapter and a member of the Society's Women in Safety Engineering and Young Professionals in SH&E common interest groups.

Inhaling diacetyl can result in fatigue, fever, night sweats and weight loss, as well as respiratory effects such as cough, difficulty breathing and occupational asthma.

tom-specific questions (e.g., symptoms displayed, where they first started, whether others show the same symptoms), occupational exposures and medical history (Kreiss, 2002; OSHA, 2002). Answers to these questions can provide valuable feedback and input, and lead to the correct diagnosis.

A medical professional also can conduct a pulmonary function test (PFT) or spirometry to assess a person's lung function (NIOSH, 2003a, b). This test can help identify obstructed or restricted airways, which signify respiratory problems (NIOSH, 2003a, b). Patients with abnormal spirometry results are often prescribed asthma medication to determine whether the airway obstruction is temporary or permanent (NIOSH, 2003a, b).

If the obstruction does not improve with the use of medication, then chest X-rays, CAT scans or lung biopsies can be performed to further identify problems in the respiratory tract (OSHA, 2002). Patients diagnosed with bronchiolitis obliterans are typically treated with steroids and informed about how to avoid aggravating their condition (OSHA, 2002). In extreme cases, lung transplants may be recommended (NIOSH, 2003a, b).

Historical exposure data and occupational air monitoring samples can be analyzed to identify links between occupational exposure to diacetyl and bronchiolitis obliterans. Frits and colleagues (Frits, Rooyackers, Prokop, et al., 2007; Frits, Smit, Houba, et al., 2008) investigated diacetyl exposure. They evaluated exposure data from numerous worksites and spirometry results from many workers. The documentation supported the investigation findings that diacetyl produced an occupational hazard to workers since many of them displayed signs and symptoms of bronchiolitis obliterans—mirroring NIOSH's findings (Kanwal & Kullman, 2007).

Exposure Limits

Agencies such as OSHA, NIOSH and American Conference of Governmental Industrial Hygienists (ACGIH) develop safety standards and guidelines to protect workers from hazards, including occupational exposures. At the federal level, no agency has established a permissible exposure limit (PEL), recommended exposure limit (REL) or threshold limit value (TLV) for diacetyl. California's Occupational Safety and Health Program does, however, regulate diacetyl at the state level, which means facilities in the state of California that have exposure to diacetyl must follow this standard (*OHS Online*, 2010). The standard "requires employers covered by the standard to create a regulated area for each process using diacetyl, unless the process is enclosed."

Although diacetyl exposure is not currently regulated at the federal level, multiple agencies have taken several steps to ensure the safety of workers with exposures to diacetyl. In August 2011, NIOSH drafted a proposed REL of 5 parts per billion (ppb) as an 8-hour, time-weighted average (TWA) during a 40-hour work week to protect workers against short-term exposures to diacetyl.

Industries & Jobs Using Diacetyl & Substitutes

- Flavoring manufacturing plants
- Facilities where flavors containing diacetyl or substitutes are used (e.g., snack foods, baked good, candy)
- Jobs at or near areas where diacetyl or flavors containing diacetyl are mixed, weighed, poured, transferred and handled
- Quality assurance jobs
- Cleaning operations
- Laboratory jobs
- Maintenance operations

Note. *From Worker Alert: Diacetyl and Substitutes, by OSHA, 2010, Washington, DC: DOL, Author.*

Does This Product Contain Diacetyl?

- Review the MSDS for each ingredient.
- Look under the Hazardous Ingredients section on the MSDS.
- Search for the word *diacetyl* or *CAS #431-03-8*.

In addition, OSHA (2011) added diacetyl and all diacetyl substitutes with the alpha-diketone structure, including 2,3-pentanedione, to its NEP. The agency (2008) also established the targeted diacetyl concentration of 0.5 parts per million (ppm) (1.76 mg/m^3) for a workplace where diacetyl is present.

Control Measures

NIOSH (2007a, b) recommends several controls to reduce hazardous exposures associated with diacetyl. These include substitution, engineering and administrative controls, education, PPE, and exposure and worker health monitoring.

Substitution

Substitution can effectively reduce or eliminate an existing hazard. Numerous substitutes have been developed to replace diacetyl to reduce employee exposure. These substitutes have not been extensively tested, so it is unknown whether they are safer than diacetyl (OSHA, 2010a, b). Before selecting a substitute, an employer should analyze and evaluate any substance's hazards so the safest and healthiest substitution can be selected.

Engineering Controls

Engineering controls are the preferred method to minimize diacetyl exposure. Sites should evaluate work areas and select controls that are functional and mesh with site setup. OSHA (2011a, c) and NIOSH (2003a, b) suggest several engineering controls:

- Closed systems. An enclosed process can reduce the concentration of airborne diacetyl.
- Ventilation. Local exhaust ventilation (LEV) can reduce the concentration of airborne diacetyl and remove diacetyl from the worker's breathing zone. These systems should be located near operations that produce high diacetyl exposure levels. Separate ventilation systems can be utilized between areas where diacetyl exposure is high versus low. It is best to not rely on filtration systems since some will cause hazardous vapors to circulate back into the work area. Maintain negative air pressure in rooms with higher concentrations to prevent the air from moving into other noncontaminated areas (OSHA, 2007a, b). Ventilation should be appropriately maintained and inspected as well.
- Isolation. Areas with higher concentrations of diacetyl, such as mixing rooms, spots near open tanks of oils or flavorings, and quality control areas, can be isolated from the immediate production room. Use doors, walls and other barriers to isolate the processes. Depending on exposure levels, personnel entering these areas may need to wear PPE.
- Reducing temperatures. When diacetyl is heated, vapors are produced and disperse through the air, making the substance more volatile and easier to inhale. Facilities should keep temperatures as low as possible while any flavorings are being heated. This limits the amount of vapors being produced and minimizes occupational exposure.

Administrative Controls

All stakeholders should partner to create administrative controls and form good work practices to prevent exposure to diacetyl. Recommended controls (NIOSH, 2003a, b; OSHA, 2010a, b) include the following:

1) Employ good housekeeping procedures. Promptly respond to spills. Avoid using compressed air to clean up powders that may contain diacetyl.

2) Use tight-sealing containers. A tight seal will prevent flavoring from being spilled or blown into the air.

3) Limit access. Limit the number of employees in areas where higher concentrations of diacetyl may be present. Train personnel how to minimize personal exposures.

Education

Worker awareness and education are essential. Workers should be educated about products that may produce diacetyl exposure and know how to protect themselves against those hazards. Employees should be trained to recognize and understand hazard warnings, workplace postings, container labels, and the signs and symptoms of diacetyl-related illness (NIOSH, 2003a, b). They also should know where to obtain hazard information regarding each product, such as MSDS.

Personal Protective Equipment

PPE can provide additional skin, eye and respiratory tract protection to workers exposed to diacetyl (NIOSH, 2003a, b). According to OSHA (2007a, b), PPE made of butyl rubber, Teflon or Tychem provides adequate protection against diacetyl. Chemical-resistant gloves, aprons and sleeves, and tight-fitting goggles can be used to protect against skin irritation and eye injuries resulting from skin contact, splashes and vapor exposures (OSHA, 2002).

The worksite should be evaluated to determine the need for respiratory protection equipment; this can be difficult in the absence of an OSHA PEL, NIOSH REL or ACGIH TLV. According to OSHA (2002), "respiratory protection in mixing rooms should be mandatory regardless of the amount of time employees spend in the room."

OSHA (2002) and NIOSH (2003a, b) recommend that mixing-room workers be provided with a half-mask air-purifying respirator equipped with an organic cartridge and particulate filters. Other options should be considered in warmer work areas where vapor exposures may be more prevalent. In these areas, a supplied air respirator or powered air-puri-

fying respirator with organic cartridges and particulate filters can be used. If eye protection is required, then a full-face piece respirator should be considered (OSHA, 2007a, b). OSHA 29 CFR 1910.134 must be followed when respirators are used.

Exposure Monitoring

Exposure monitoring helps to identify hazards and to determine whether controls are adequate. Such monitoring is critical in an industry where employees may be exposed to many different substances in various forms. Exposure monitoring can detect the levels of harmful substances, such as diacetyl, and pinpoint hazardous areas in the workplace. Before conducting exposure monitoring, an employer should assess current work practices and controls implemented at the worksite to determine whether current controls are working properly or whether additional controls are needed.

Industrial Hygiene Implementation Plan

An industrial hygiene implementation plan (IHIP) can be developed to prioritize and schedule monitoring for detectable amounts of diacetyl; the sampling should be conducted by qualified individuals. To obtain accurate results, the plan should address the rotation of conducting both personal and area samples. The plan should not only include air sampling strategies for diacetyl, but also sampling for any other flavoring chemical with an established PEL, REL or TLV (NIOSH, 2003a, b). Sampling for total dust and respirable dust also should be considered because diacetyl can be present in a solid form.

Exposure monitoring should be conducted when diacetyl exposures are expected to be at their highest. Monitoring provides valuable data on occupational exposures and can help determine the extent of required controls. Sampling data gathered after controls are implemented can help determine whether controls are reducing occupational exposures to diacetyl or other flavoring substances (OSHA, 2010a, b). High-hazard areas should be continually monitored to ensure worker safety.

Because established exposure limits are lacking, OSHA and NIOSH have developed sampling and analytical methodologies for evaluating diacetyl exposures. NIOSH sampling method 2557 utilizes sorbent tubes and a personal sampling pump calibrated to a flow rate of between 0.01 and 0.2 L/min. The sample is collected by opening the sorbent tube, connecting it to a sample pump and pulling air through the sorbent tube with the pump. The tube is then sealed and analyzed at a laboratory using gas chromatography with a flame ionization detector (FID). Results are compared against NIOSH's proposed REL of 5 ppb as an 8-hour TWA during a 40-hour work week. It should be noted that NIOSH (2003a, b) has reported that the relative humidity of the sampling area can lead to inaccurate and unreliable results.

OSHA sampling method 1013 utilizes silica gel sorbent tubes with a glass fiber filter and a personal sampling pump calibrated to a recommended flow rate of 0.05 L/min for the TWA or 0.2 L/min to evaluate a short-term exposure. Since diacetyl levels may be affected by sunlight, the sorbent tubes must be covered with foil or a tube cover to protect the sample from light. The sample is collected by opening the sorbent tube, connecting it to a sample pump and pulling air through the sorbent tube with the pump. The recommended sampling time is 180 minutes to assess the TWA and 15 minutes to determine the short-term exposure. The tube is then sealed and its contents are analyzed at a laboratory using gas chromatography with a FID. Results are compared against the agency's established targeted concentration of 0.5 ppm for a workplace where diacetyl is present (OSHA, 2008).

Worker Health Monitoring

Workers should be continuously monitored wherever diacetyl exposure is possible. A medical surveillance program should be in place to manage these exposures. This program should encompass prejob and annual spirometry testing to determine whether workers are experiencing health effects due to occupational exposure. Spirometry testing can be conducted as often as needed, especially if a worker is exhibiting signs and symptoms of respiratory illnesses that may be associated with diacetyl exposure (OSHA, 2010). Information gathered from these tests can provide insight about worker safety and health and also identify work areas where control measures are needed.

Keys to Prevention

Both employers and employees should take the initiative and extra steps necessary to prevent diacetyl exposure.

Employer Prevention

To promote safety and health, employers can:

1) Develop a training program to inform workers on the dangers of diacetyl exposure.
2) Implement control measures where needed.
3) Establish and enforce good work practices.
4) Create and implement a continuous monitoring plan.
5) Provide adequate PPE where required.
6) Stress the importance of the medical surveillance program.

Diacetyl Exposure Limits

- Diacetyl currently is not regulated on a federal level, so there is no established OSHA PEL, NIOSH REL or ACGIH TLV.
- The State of California regulates diacetyl on a state level, addressing the need for a regulated area where diacetyl is handled.
- NIOSH proposed an REL of 5 ppb as an 8-hour TWA during a 40-hour work week.
- OSHA established a targeted diacetyl concentration of 0.5 ppm for a workplace where diacetyl is present.

7) Track and trend reported signs of illness that may be associated with diacetyl exposure (NIOSH, 2003a, b; OSHA, 2010a, b).

Worker Prevention

Workers can take steps to ensure their safety when exposed to or potentially exposed to diacetyl:

1) Utilize information provided on MSDS.
2) Use in-place control measures, including PPE.
3) Tightly seal all containers when not in use.
4) Participate in the medical surveillance program.

Actively report any signs or symptoms that may be associated with diacetyl exposure (NIOSH, 2003a, b; OSHA, 2010a, b). **PS**

References

Frits, G.B., Smit, L.A., Houba, R., et al. (2008). A cross-sectional study of lung function and respiratory symptoms among chemical workers producing diacetyl for food flavorings. *Occupational Environmental Medicine, 66*, 105-110. doi:10.1136/oem.2008.039560

Frits, G.B., Rooyackers, J.M., Prokop, M., et al. (2007). Bronchiolitis obliterans syndrome in chemical workers producing diacetyl for food flavorings. *American Journal of Respiratory and Critical Care Medicine, 176*, 498-504. doi:10.1164/rccm.200611-1620OC

Kanwal, R. & Kullman, G. (2007). Report on severe fixed obstructive lung disease in workers at a flavoring manufacturing plant (NIOSH Health Hazard Evaluation Report No. 2006-030303043). Washington, DC: U.S. Department of Health and Human Services (DHHS), CDC, NIOSH. Retrieved from **www.cdc.gov/niosh/hhe/reports/pdfs/2006-0303-3043.pdf**.

Kreiss, K. (2002). Clinical bronchiolitis obliterans in workers at a microwave-popcorn plant. *New England Journal of Medicine, 347*(5), 330-338.

NIOSH. (2003a). Diacetyl, 2557. Washington, DC: DHHS, CDC, NIOSH. Retrieved from **www.cdc.gov/niosh/docs/2003-154/pdfs/2557.pdf**.

NIOSH. (2003b). Preventing lung disease in workers who use or make flavorings (NIOSH Publication No. 2004-110). Washington, DC: DHHS, CDC, NIOSH. Retrieved from **www.cdc.gov/niosh/docs/2004-110/pdfs/2004-110.pdf**.

NIOSH. (2006). Hazard evaluation and technical assistance report: Gilster-Mary Lee Corporation, Jasper, MO (NIOSH HETA Report 41 No. 2000-0401-2991). Washington, DC: DHHS, CDC, Author.

NIOSH. (2007a). Hazard evaluation and technical assistance report: Carmi Flavor and Fragrance Company Inc. (NIOSH HETA Report No. 2006-0303-3043). Washington, DC: DHHS, CDC, Author.

NIOSH. (2007b). Hazard evaluation and technical assistance report: Yatsko's Popcorn (NIOSH HETA Report No. 2006-019508-3044). Washington, DC: DHHS, CDC, Author.

NIOSH. (2011). Diacetyl and 2,3–pentanedione: NIOSH seeks comment on draft criteria document. Washington, DC: DHHS, CDC, Author. Retrieved from **www.cdc.gov/niosh/updates/upd-08-15-11.html**.

OSHA. (2002). Recommended preventive and control measures to reduce the risk of obstructive lung disease among workers in the microwave popcorn packaging industry. Washington, DC: U.S. Department of Labor, (DOL), Author. Retrieved from **www.osha.gov/SLTC/flavoringlung/preventativecontrolmeasures_regionvii.html**.

OSHA. (2007a). Hazard communication guidance for diacetyl and food flavorings containing diacetyl. Washington, DC: DOL, Author. Retrieved from **www.osha.gov/dsg/guidance/diacetyl-guidance.html**.

OSHA. (2007b). National emphasis program: Microwave popcorn processing plants (CPL 03-00-005). Washington, DC: DOL, Author. Retrieved from **www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=DIRECTIVES&p_id=3649**.

OSHA. (2008). Acetoin/diacetyl. Washington, DC: DOL, Author. Retrieved from **www.osha.gov/dts/sltc/methods/validated/1013/1013.html**.

OSHA. (2010a). Occupational exposure to flavoring substances: Health effects and hazard control (SHIB 10-14-2010). Washington, DC: DOL, Author. Retrieved from **www.osha.gov/dts/shib/shib10142010.html**.

OSHA. (2010b). Worker alert: Diacetyl and substitutes. Washington, DC: DOL, Author. Retrieved from **www.osha.gov/SLTC/flavoringlung/diacetyl_worker_alert.html**.

OSHA. (2011a). Flavorings-related lung disease. Washington, DC: DOL, Author. Retrieved from **www.osha.gov/SLTC/flavoringlung/index.html**.

OSHA. (2011b). National emphasis program: Microwave popcorn processing plants (CPL 03). Washington, DC: DOL, Author. Retrieved from **www.in.gov/dol/files/CPL_03_DIR_11-01.pdf**.

OSHA. (2011c). OSHA revises national emphasis program to focus on protecting workers from exposure to diacetyl and diacetyl substitutes [Press release]. Washington, DC: DOL, Author. Retrieved from **www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=NEWS_RELEASES&p_id=19140**.

OHS Online. (2010). California becomes first state to set safety guidelines for diacetyl. Retrieved from **http://ohsonline.com/articles/2010/12/03/california-becomes-first-state-to-set-safety-guidelines-for-diacetyl.aspx?sc_lang=en**.

U.S. Food and Drug Administration. (2011). Select committee on GRAS substances (SCOGS) opinion: Diacetyl. Washington, DC: Author. Retrieved from **www.fda.gov/Food/FoodIngredientsPackaging/GenerallyRecognizedasSafeGRAS/GRASSubstancesSCOGSDatabase/ucm261273.htm**.