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Preventing Lung Disease in Workers Who Use or Make Flavorings

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

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ALERT

Preventing Lung Disease in Workers Who Use or Make Flavorings

WARNING!

Breathing certain flavoring chemicals in the workplace may lead to severe lung disease.

Flavorings are complex mixtures of natural and manmade ingredients that are added to many food products in the production process. Depending on the flavoring and the process, workers may be exposed to hazardous flavorings or flavoring ingredients in the form of vapors, dusts, or sprays.

Workers who make, use, or work near flavorings or flavoring ingredients should take the following steps to protect their health:

- Ask your supervisor for training on the hazards associated with the flavorings and ingredients.
- Read labels on containers and material safety data sheets (MSDSs) on the flavorings and ingredients.
- Know and use the exposure control devices and work practices that keep flavorings and ingredients out of the air in your workplace.
- Keep containers of flavorings and chemical ingredients tightly closed when not in use so that their contents do not get into the workplace air.
- Understand when and how to wear a respirator (protective breathing mask) and other personal protective equipment (such as gloves and eye goggles) that your employer may provide.

- Participate in breathing tests provided by your employer.
- Promptly report any persistent shortness of breath or cough, or any problems with your eyes, nose, throat, or skin to your supervisor and your doctor. When you report your symptoms, show them a copy of this Alert.

Companies that use or make flavorings should take the following steps to protect the health of their workers:

- Limit hazardous worker exposures:
 - Consider substitution of less hazardous flavoring ingredients or formulations where feasible.
 - Use closed production processes (i.e., avoid handling of open containers of flavorings and ingredients).
 - Apply effective local exhaust ventilation as well as general dilution ventilation in places where flavorings or their ingredients are handled.
 - Isolate mixing and other high-exposure processes from the rest of the workplace and maintain these work areas under negative air pressure.
 - Use the lowest temperatures necessary if heated processes are used.
 - Establish and enforce work practices to limit release of chemical vapors and dust into the workplace air.

- Monitor air concentrations of flavoring ingredients to assure that control efforts are limiting exposures.
- Train workers on the potential for lung disease and other health effects from exposure to flavoring-related chemicals and on ways exposure can be avoided or minimized.
- Assure appropriate labeling of containers and posting of warnings.
- Provide workers with appropriate respiratory protection if they are at risk for hazardous respiratory exposure to flavorings or their ingredients
 - while optimal exposure controls are being implemented,
 - when controls are not working properly because of a breakdown or maintenance procedures, and
 - when even the lowest exposures that can be achieved are still associated with potential risk.
- Provide workers with other appropriate personal protective equipment (e.g., gloves, masks, and goggles) if they are at risk for hazardous eye and skin exposure.
- Provide breathing tests (spirometry) before the first exposure, and on a regular basis thereafter, to all workers at risk of hazardous exposure to flavorings or their ingredients. Refer workers for evaluation by a physician if they have abnormal test results, an accelerated drop in test results over time, or persistent symptoms.
- Assess the patterns of reported symptoms and lung function results among the entire workforce to identify work areas, processes, or exposures that may require more intensive intervention to prevent further adverse health effects.

For additional information, see ***NIOSH Alert: Preventing Lung Disease in Workers Who Use or Make Flavorings*** [DHHS (NIOSH) Publication No. 2004-110]. Single copies of the Alert are available free from the following:

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WARNING!

Breathing certain flavoring chemicals in the workplace may lead to severe lung disease.

The National Institute for Occupational Safety and Health (NIOSH) requests assistance in preventing lung disease and other health effects in workers who use or make flavorings. The occurrence of severe lung disease in workers who make flavorings or use them to produce microwave popcorn has revealed an unrecognized occupational health risk. Flavorings are often complex mixtures of many chemicals [Conning 2000]. The safety of these chemicals is usually established for humans consuming small amounts in food [Pollitt 2000], not for food industry workers inhaling them. Production workers employed by flavoring manufacturers (or those who use flavorings in the production process) often handle a large number of chemicals, many of which can be highly irritating to breathe in high concentrations.

This Alert describes health effects that may occur because of workplace exposure to some flavorings or their ingredients, gives examples of workplace settings in which illness has occurred, and recommends steps that companies and workers should take to prevent hazardous exposures.

BACKGROUND

NIOSH has investigated the occurrence of severe lung disease in workers at a microwave popcorn packaging plant. Eight former workers at this plant developed illness characterized by fixed airways obstruction on lung function tests [Akpinar-Elci et al. 2002]. An evaluation of the current workforce at this plant showed an association between exposure to vapors from flavorings used in the production process and decreased lung function [Kreiss et al. 2002a]. Similar fixed obstructive lung disease has also occurred in workers at other plants that use or manufacture flavorings [NIOSH 1986; Lockey et al. 2002]. In animal tests, inhaling vapors from a heated butter flavoring used in microwave popcorn production caused severe injury to airways [Hubbs et al. 2002a].

Medical test results in affected workers (including some lung biopsy results) are consistent with bronchiolitis obliterans, an uncommon lung disease characterized by fixed airways obstruction [Akpinar-Elci et al. 2002]. In bronchiolitis obliterans, inflammation and scarring occur in the smallest

airways of the lung and can lead to severe and disabling shortness of breath. The disease has many known causes such as inhalation of certain chemicals, certain bacterial and viral infections, organ transplantation, and reactions to certain medications [King 2000]. Known causes of bronchiolitis obliterans due to occupational or other environmental exposures include gases such as nitrogen oxides (e.g., silo gas), sulfur dioxide, chlorine, ammonia, phosgene, and other irritant gases [King 1998]. Recent NIOSH investigations strongly suggest that some flavoring chemicals can also cause bronchiolitis obliterans in the workplace. (Some workers exposed to flavorings in one of these plants were also found to have occupational asthma.)

HEALTH EFFECTS

The main respiratory symptoms experienced by workers affected by fixed airways obstruction include cough (usually without phlegm) and shortness of breath on exertion. These symptoms typically do not improve when the worker goes home at the end of the workday or on weekends or vacations. The severity of the lung symptoms can range from only a mild cough to severe cough and shortness of breath on exertion. Usually these symptoms are gradual in onset and progressive, but severe symptoms can occur suddenly. Some workers may experience fever, night sweats, and weight loss. Before arriving at a final diagnosis, doctors of affected workers initially thought that the symptoms might be due to asthma, chronic bronchitis, emphysema, pneumonia, or smoking. Severe cases may not respond to medical treatment. Affected workers generally notice a gradual reduction or

cessation of cough years after they are no longer exposed to flavoring vapors, but shortness of breath on exertion persists. Several with very severe disease were placed on lung transplant waiting lists. Workers exposed to flavorings may also experience eye, nose, throat, and skin irritation. In some cases, chemical eye burns have required medical treatment.

Medical Evaluation

Medical testing may reveal several of the following findings:

- Spirometry, a type of breathing test,
 - most often shows fixed airways obstruction (i.e., difficulty blowing air out fast and no improvement with asthma medications), and
 - sometimes shows restriction (i.e., decreased ability to fully expand the lungs).
- Lung volumes may show hyperinflation (i.e., too much air in the lungs due to air trapping beyond obstructed airways).
- Diffusing capacity of the lung (DLCO) is generally normal, especially early in the disease.
- Chest X-rays are usually normal but may show hyperinflation.
- High-resolution computerized tomography scans of the chest at full inspiration and expiration may reveal heterogeneous air trapping on the expiratory view as well as haziness and thickened airway walls.
- Lung biopsies may reveal evidence of constrictive bronchiolitis obliterans (i.e.,

severe narrowing or complete obstruction of the small airways). An open lung biopsy, such as by thoracoscopy, is more likely to be diagnostic than a transbronchial biopsy. Special processing, staining, and review of multiple tissue sections may be necessary for a diagnosis.

CURRENT EXPOSURE LIMITS

Flavorings are composed of various natural and manmade substances. They may consist of a single substance, but more often they are complex mixtures of several substances. The Flavor and Extract Manufacturers Association evaluates flavoring ingredients to determine whether they are "generally recognized as safe" (GRAS) under the conditions of intended use through food consumption. Though considered safe to eat, ingredients may be harmful to breathe in the forms and concentrations to which food and chemical industry workers may be exposed.

Occupational exposure guidelines have been developed for only a small number of the thousands of ingredients used in flavorings. For example, Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs) and/or NIOSH recommended exposure limits (RELs) have been established for only 46 (<5%) of the 1,037 flavoring ingredients considered by the flavorings industry to represent potential respiratory hazards due to possible volatility and irritant properties (alpha, beta-unsaturated aldehydes and ketones, aliphatic aldehydes, aliphatic carboxylic acids, aliphatic amines, and aliphatic aromatic thiols and sulfides) [Hallagan 2002] (see Appendix). Material safety data sheets (MSDSs) contain

information about known occupational hazards of specific chemicals, but they may not be based on the most up-to-date information in the case of newly recognized occupational health risks.

CASE CLUSTER REPORTS

Case Cluster 1

Four men and four women, aged 29 to 53, who had worked at a single microwave popcorn packaging plant (popcorn plant A) developed fixed obstructive airways disease. One of these former workers and another worker later identified at the same plant had lung biopsy findings consistent with bronchiolitis obliterans [Akpinar-Elci et al. 2002]. The cases occurred sporadically over several years. Four had worked as mixers of a heated soybean oil, salt, and butter flavoring mixture; the butter flavoring was poured by hand from open buckets into open mixing tanks (see Figure 1). The other four had packaged microwave popcorn near the room where the oil and flavorings were mixed. Five had never smoked or smoked very little. Initial symptoms included cough, shortness of breath on exertion, and wheeze. Most had gradual onset of symptoms between 5 months and 5 years after starting work at the plant. Spirometry testing revealed severe airways obstruction in six workers. All eight had normal chest X-rays; four of six tested had normal DLCOs. Medical treatment with corticosteroid medication was not effective. Most had severe disease by the time they were referred to lung specialists and four were placed on lung transplant lists. Their coughs diminished months to years after leaving employment, but their shortness of breath on exertion did not.



Figure 1. Mixing room, Case Cluster 1. The large mixing tank holds heated oil and butter flavoring mixture. Note loose-fitting lid, spillage on the outside of the tank, lack of local exhaust ventilation, and open 5-gallon buckets used to manually transfer concentrated butter flavoring from the smaller heated tanks to the large mixing tank.

Spirometry tests of 117 of 135 current workers employed at this plant revealed that the number of workers with airways obstruction was 3 times higher than expected [Kreiss et al. 2002a]. Almost all chest X-rays and DLCOs in these workers were normal. Workers with greater past exposure to flavoring vapors were significantly more likely to have abnormal spirometry test results than those with less exposure. Quality control workers, each of whom popped about 100 bags of microwave popcorn each shift in a small room with little ventilation, also had higher rates of abnormal lung function. Many workers also reported developing skin problems after starting work at the plant.

Case Cluster 2

Five workers at a flavorings manufacturing company developed fixed airways obstruction [Lockey et al. 2002]. All five

affected workers were relatively young and none smoked. One was a 38-year-old worker who became short of breath and started coughing within seconds after adding 30 gallons of acetaldehyde to a flavoring mixture. Her shortness of breath resolved after a few minutes, but her cough persisted. Two months later, she noted shortness of breath on exertion. Spirometry tests done after the onset of symptoms showed fixed airways obstruction; spirometry test results before starting work at the plant had been normal. She did not respond to treatment with medications. Similar symptoms were experienced by the other four workers who developed fixed airways obstruction while working at the plant. No further lung function loss was noted over several years after removal from exposure.

Case Cluster 3

Two young, nonsmoking, previously healthy workers at a plant producing flavorings for the baking industry developed severe fixed airways obstruction within several months of starting to work at the plant [NIOSH 1986]. Both worked in a room where liquid and powdered flavorings were combined with starch and flour in large mixers. Both developed shortness of breath on exertion and persistent cough. Spirometry tests revealed severe fixed airways obstruction. DLCOs and chest X-rays were normal. Neither worker had a significant clinical improvement in response to bronchodilator and corticosteroid medications. After being away from the workplace for several months, both affected workers had persistent severe shortness of breath on exertion. Two former mixing room workers who were tested were also found to have mild to moderate airways obstruction.

Case Cluster 4

A 54-year-old mixer of oil and butter flavorings at a microwave popcorn plant (popcorn plant B) was referred for evaluation of a chronic cough [Parmet and Von Essen 2002]. Spirometry tests indicated fixed airways obstruction. This worker reported having a chronic cough since beginning work at the plant 3 years earlier. His cough became noticeably worse when he used a new butter flavoring mixture. He experienced some improvement in respiratory symptoms and lung function with cessation of exposure and treatment with corticosteroid medication. Five of the six workers exposed to flavoring vapors in the plant developed chemical eye burns after using the new flavoring mixture. Their eye problems resolved over several weeks with medical treatment and cessation of exposure [Kanwal 2002a].

Case Cluster 5

A NIOSH investigation at a microwave popcorn plant (popcorn plant C) found an obstructive pattern on lung function testing in 11 of 41 production workers—between 2 and 3 times the number expected. The obstruction was fixed (i.e., did not respond to bronchodilator medication), and DLCO was normal in most of the affected workers who underwent diffusing capacity testing. In this plant, the mixing and holding tanks for heated oil and butter flavoring were located in a room where the packaging lines and all production workers were also located [Sahakian 2003].

Case Cluster 6

A 37 year-old mixer of heated soybean oil and flavorings at a microwave popcorn plant (popcorn plant D) was found to have

severe fixed airways obstruction. He had worked as mixer for 7 years. Spirometry testing done during his first 3 years as a mixer revealed that his lung function was declining at a greater than expected rate. He developed progressive shortness of breath on exertion starting in his fourth year as a mixer.

In this plant, the mixing and holding tanks for heated soybean oil and flavorings have local exhaust ventilation and are located in a room that has separate ventilation from the rest of the plant. A NIOSH investigation found an excess of abnormal spirometry tests among current workers who had worked as mixers (6 of 13; half with fixed obstruction). No significant excess of spirometry abnormalities was found among packaging line workers. Respirators (protective breathing masks) were provided but not always used by mixers when exposed to flavorings [Kanwal 2002b].

CONCLUSIONS

Case clusters of fixed obstructive lung disease, one with biopsy evidence of bronchiolitis obliterans, have been documented among workers at several different plants where flavorings are used or where chemicals are handled in the production of flavorings. Recent attention has been largely focused on workers exposed to volatile chemicals in butter flavorings at microwave popcorn plants, but other reports indicate that other flavoring and food manufacturing workers exposed to various flavorings may also be at risk.

Little is currently known about which chemicals used in flavorings have the potential to cause lung disease and other

health effects, and what workplace exposure concentrations are safe. As part of ongoing investigations into airways disease in microwave popcorn workers, NIOSH has recently undertaken animal experiments to evaluate individual butter flavoring chemicals. Results of an animal study indicate that exposure to vapors from diacetyl, a chemical used to impart butter-like flavor, causes airway injury, though perhaps to a smaller extent than that caused by exposure to vapors from the intact butter flavoring mixture itself [Kreiss et al. 2002b; Hubbs et al. 2002b].

Most chemicals used in flavorings have not been tested for respiratory toxicity via the inhalation route, and occupational exposure limits have been established for only a relatively small number of these chemicals. Although much remains unknown regarding the toxicity of flavoring-related chemicals, employers and workers can take steps to address working conditions and work practices that place workers at risk.

RECOMMENDATIONS

The following recommendations are provided to reduce hazardous exposures associated with the use or manufacture of flavorings. In general, NIOSH recommends that employers and workers implement controls to limit worker exposure. In order of preference, the major types of controls include the following:

1. Substitution
2. Engineering controls
3. Administrative controls
4. Education
5. Personal protective equipment
6. Exposure and worker health monitoring

Substitution

Substituting a less hazardous material can effectively reduce an existing hazard. However, substitution does not always represent a feasible or definitive approach. An adequate substitute may not exist; or, as with flavoring mixtures, the exposures may be complex and toxicities may be inadequately understood. Therefore, do the following when considering substitution:

- Exercise extreme care when selecting substitutes.
- Consider the possible adverse health effects of any candidate substitutes.
- Remember that as a general rule, flavoring formulations designed to release less volatile chemicals or respirable powder into the air during handling may pose less risk to workers.

Engineering Controls

Engineering controls are the primary methods for minimizing exposure associated with the use or manufacture of potentially hazardous flavorings. Examples include closed production systems (e.g., to eliminate handling open containers of flavorings or their chemical ingredients for placement into mixing tanks), adequate ventilation, and isolation.

- Whenever possible, use closed processes to transfer flavorings or their chemical ingredients.
- Isolate the mixing room and other areas where flavorings and their ingredients are openly handled. Maintain these work areas under negative air pressure relative to the rest of the plant.

- Use local exhaust ventilation of tanks and other sources of potential exposure (e.g., places where flavorings are openly weighed or measured) as well as general dilution ventilation of the work area to eliminate or reduce possible worker exposures. Obtain information about the design of appropriate ventilation systems from a qualified ventilation engineer or from *Industrial Ventilation—A Manual of Recommended Practice* [ACGIH 2001].
 - Check ventilation equipment regularly for adequate performance, especially in areas where flavorings and their ingredients are handled (e.g., mixing room) and in adjacent work areas. Also perform checks whenever a process change is made or a problem is suspected.
 - For processes involving heating of flavorings, keep the temperature as low as possible to minimize emissions of volatile chemicals into the air.
- Do not use compressed air for cleaning powdered flavorings or ingredients, as this will increase concentrations of airborne particulate.
 - Use special caution when removing residual chemicals from tanks and other containers with steam or hot water, as this may increase exposure to volatile chemical vapors.
 - Clean up spills of flavorings or their ingredients promptly using procedures and appropriate protective equipment designed to limit exposure.
- Restrict access to all areas where flavorings are openly handled; only essential workers should enter these areas and only when properly protected (see section on personal protective equipment).

Administrative Controls

- Establish and enforce work practices to limit release of chemicals and dust into the workplace air when flavorings or their ingredients are handled.
- Tightly seal containers with unused or residual amounts of flavorings or their ingredients.
- Maintain good general housekeeping in any areas where flavorings or their ingredients are handled.
- Establish standard procedures for cleaning the workplace, tanks and other containers, and spills.

Employer and Worker Education

Employer awareness of hazardous exposures in the production process and communication of this information to workers are vital elements in an optimal occupational safety and health program.

- Inform workers about any materials that may contain flavoring agents and tell them the nature of the hazard.
- Provide general information and specific hazard warnings through workplace postings, container labeling, MSDSs, and training.
- Train workers regarding the means available at the facility to eliminate or limit exposure and how they can take action to limit potential exposures for themselves and fellow workers.

- Inform workers about symptoms that may indicate a flavoring-related health problem. Advise them to report these symptoms to their supervisors and physicians.

Personal Protective Equipment

Whenever the substances and amounts present in a plant or work area pose a potential hazard, provide personal protective equipment to protect workers from skin, eye, and respiratory tract irritation and other adverse health effects.

Skin and eye protection

- Enforce the use of chemical-resistant gloves and tight-fitting goggles for workers with potential skin and eye exposure to irritant flavorings or their chemical ingredients.
- Establish specific guidance about when to use the equipment for each job, based on knowledge of the tasks performed, substances involved, and an assessment of potential exposures.

Respiratory protection

The use of respirators is the least preferred method of controlling worker exposures to respiratory hazards.

- Do not use respirators as the primary control for routine operations. However, they may be needed and used while optimal engineering controls and work practices are being implemented, during some short-duration maintenance procedures, and during emergencies.
- Use respirators for exposure situations in which even the lowest concentrations achievable with engineering controls

are still associated with risk (see section on worker health monitoring).

- The minimum protective respirator that should be used for workers exposed to flavorings or their chemical ingredients is a NIOSH-certified half-mask, negative-pressure respirator with organic vapor cartridges or canisters and particulate filters.
- Use a full-facepiece respirator for eye protection as well as additional respiratory protection.
- Consider other respirators for workers exposed to flavorings or their chemical ingredients: powered, air-purifying respirators (with organic vapor cartridges or canisters and particulate filters) and, for maximum respiratory protection, supplied-air respirators.
- Before using respirators, set up a written respiratory protection program that meets the requirements of the OSHA respiratory protection standard [29 CFR* 1910.134].
- Designate a trained employee or supervisor to run the program and evaluate its effectiveness. Make sure that the designated person's training or experience is appropriate to the level of complexity of the program.
- Ensure that respirators selected for use are certified by NIOSH according to 42 CFR 84.

*Code of Federal Regulations. See CFR in references.

- Implement a change schedule for canisters and cartridges based on objective information or data that will ensure that canisters and cartridges are changed before the end of their service lives.
- Include the following in the respiratory protection program:
 - Procedures for selecting respirators
 - Medical evaluations of workers required to use respirators
 - Fit-testing procedures for tight-fitting respirators
 - Procedures for proper use of respirators in routine and reasonably foreseeable emergency situations
 - Procedures and schedules for cleaning, disinfecting, storing, inspecting, repairing, discarding, and otherwise maintaining respirators
 - Procedures to ensure adequate quality, quantity, and flow of breathing air for atmosphere-supplying respirators
 - Training of workers in the respiratory hazards to which they are potentially exposed during routine and emergency situations
 - Training of workers in the proper use of respirators, including putting them on and removing them, any limitations on their use, and their maintenance
 - Procedures for regularly evaluating the effectiveness of the program

and worker compliance with program requirements

Exposure Monitoring

- Engage the services of a certified air sampling expert to identify the volatile flavoring chemicals that are present in significant amounts in the air, and to measure the air concentrations of one or more of these chemicals as indicators of exposure.
- When applicable, measure air concentrations of total respirable dust and the air concentration of any flavoring chemical with an OSHA PEL or a NIOSH REL.
- Use repeated monitoring to determine whether new engineering controls or changes in work practices are effectively reducing exposures.
- Continue routine monitoring on a regular basis to ensure the continuing effectiveness of controls.
- If monitoring indicates that exposure concentrations have increased, thoroughly investigate engineering controls to identify problems and guide remedial actions.

Worker Health Monitoring

- Implement preplacement and regularly scheduled ascertainment of symptoms and spirometry testing of lung function for all workers with potentially hazardous exposure to flavorings or flavoring ingredients.

- Follow the latest American Thoracic Society guidelines [ATS 1995] for spirometry testing.
- Perform testing at least annually, since existing information makes it difficult to specify the interval between testing. The relatively rapid onset of severe airways obstruction in some affected workers suggests that more frequent intervals (perhaps every 3 months) may be appropriate in some situations.
- Conduct more frequent testing if abnormalities related to flavoring exposure are detected in a particular workforce. Regardless, workers should not wait for regularly scheduled testing to report symptoms.
- Promptly refer workers for further medical evaluation if they have persistent cough; persistent shortness of breath on exertion; frequent or persistent symptoms of eye, nose, throat, or skin irritation; abnormal lung function on spirometry testing; or accelerated decline in lung function. Provide the evaluating physician with a copy of this Alert. The intent is to identify and prevent progression of work-related medical conditions. The physician should advise the worker about any suspected or confirmed medical condition that may be caused or aggravated by work exposures, about recommendations for further evaluation and treatment, and specifically about any recommended restriction of the worker's exposure (including removal from the workplace) or use of personal protective equipment. The physician should provide the employer with information about recommended restrictions of the

worker's exposure or use of personal protective equipment.

- Do not rely on the absence of respiratory symptoms that occur in relation to work exposures to indicate that exposures are adequately controlled. In contrast to workers with work-related asthma, few if any workers with fixed airways obstruction from exposure to flavorings report improvement on days off work or during vacations. Also, flavoring-exposed workers who develop fixed airways obstruction may not have symptoms early in the course of their illness. Regularly scheduled spirometry is currently the best available test for early recognition of decreasing or abnormal lung function from occupational exposure to flavorings or their ingredients.

Surveillance and Disease Reporting

- Assess the patterns of reported symptoms, abnormal spirometry, physician-advised exposure restrictions, and other available information about health effects within the workforce to identify areas, processes, and exposures that may require more intensive intervention to control exposures and prevent further adverse health effects.

Physicians, workers, and employers should report to the NIOSH Division of Respiratory Disease Studies (800-232-2114) and their State health department any cases of lung disease with fixed airways obstruction or any other significant work-related lung disease in workers exposed to flavorings or flavoring ingredients. The information from such reports can help identify high-risk

work settings and guide efforts to prevent additional cases.

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1-800-35-NIOSH.

We greatly appreciate your assistance in protecting the health of U.S. workers.



John Howard, M.D., Director
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APPENDIX

Flavoring substances with OSHA PELs and/or NIOSH RELs

FEMA No.	CAS No.	Substance	Synonyms*
2003	75-07-0	Acetaldehyde	Acetic aldehyde; ethanal; ethyl aldehyde
2006	64-19-7	Acetic acid	Acetic acid (aqueous); glacial acetic acid (pure compound); ethanoic acid; methane-carboxylic acid
2055	123-92-2	Isoamyl acetate	Banana oil; isopentyl acetate; 3-methyl-1-butanol acetate; 3-methylbutyl ester of acetic acid; 3-methyl-butyl ethanoate
2057	123-51-3	Isoamyl alcohol	Primary isoamyl alcohol; fermentation amyl alcohol; fusel oil; isobutyl carbinol; isopentyl alcohol; 3-methyl-1-butanol
2170	78-93-3	2-Butanone	Ethyl methyl ketone; MEK; methyl acetone; methyl ethyl ketone
2174	123-86-4	Butyl acetate	n-Butyl acetate; n-butyl ester of acetic acid; butyl ethanoate
2175	110-19-0	Isobutyl acetate	Isobutyl ester of acetic acid; 2-methylpropyl acetate; 2-methylpropyl ester of acetic acid; β -methylpropyl ethanoate
2178	71-36-3	Butyl alcohol	n-Butyl alcohol; 1-butanol; n-butanol; 1-hydroxybutane; n-propyl carbinol
2179	78-83-1	Isobutyl alcohol	IBA; isobutanol; isopropylcarbinol; 2-methyl-1-propanol
2184	128-37-0	Butylated hydroxytoluene	BHT; dibutylated hydroxytoluene; 4-methyl-2,6-di-tert-butyl phenol; 6-di-tert-butyl-p-cresol
2205	138-22-7	Butyl lactate	n-Butyl lactate; butyl ester of 2-hydroxypropanoic acid; butyl ester of lactic acid
2414	141-78-6	Ethyl acetate	Acetic ester; acetic ether; ethyl ester of acetic acid; ethyl ethanoate
2418	140-88-5	Ethyl acrylate	Ethyl acrylate (inhibited); ethyl ester of acrylic acid; ethyl propenoate
2419	64-17-5	Ethyl alcohol	Alcohol; ethanol; EtOH; grain alcohol; cologne spirit
2434	109-94-4	Ethyl formate	Ethyl ester of formic acid; ethyl methanoate

See footnotes at end of table.

(Continued)

Flavoring substances with OSHA PELs and/or NIOSH RELs (Continued)

FEMA No.	CAS No.	Substance	Synonyms*
2487	64-18-6	Formic acid	Formic acid (85%–95% in aqueous solution); hydrogen carboxylic acid; methanoic acid
2489	98-01-1	Furfural	Fural; 2-furancarboxaldehyde; furfuraldehyde; 2-furfuraldehyde
2491	98-00-0	Furfuryl alcohol	2-Furylmethanol; 2-hydroxymethylfuran
2525	56-81-5	Glycerol	Glycerin (anhydrous); glycylic alcohol; 1,2,3-propanetriol; trihydroxypropane
2544	110-43-0	2-Heptanone	Amyl methyl ketone; n-amyl methyl ketone; methyl (n-amyl) ketone
2546	123-19-3	4-Heptanone	Dipropyl ketone; butyrene; DPK; heptan-4-one; propyl ketone
2676	79-20-9	Methyl acetate	Methyl ester of acetic acid; methyl ethanoate
2716	74-93-1	Methyl mercaptan	Mercaptomethane; methanethiol; methyl sulfhydrate
2731	108-10-1	4-Methyl-2-pentanone	Isobutyl methyl ketone; methyl isobutyl ketone; MIBK; hexone
2842	107-87-9	2-Pentanone	Ethyl acetone; methyl propyl ketone; MPK
2924	79-09-4	Propionic acid	Carboxyethane; ethane carboxylic acid; ethyl-formic acid; metacetic acid; methyl acetic acid; propanoic acid
2925	109-60-4	Propyl acetate	n-Propyl acetate; n-propyl ester of acetic acid
2926	108-21-4	Isopropyl acetate	Isopropyl ester of acetic acid; 1-methylethyl ester of acetic acid; 2-propyl acetate
2928	71-23-8	Propyl alcohol	n-Propyl alcohol; ethyl carbinol; 1-propanol; n-propanol
2929	67-63-0	Isopropyl alcohol	Dimethyl carbinol; IPA; isopropanol; 2-propanol; sec-propyl alcohol; rubbing alcohol
2966	110-86-1	Pyridine	Azabenzene; azine
3098	110-62-3	Valeraldehyde	n-Valeraldehyde; amyl aldehyde; pentanal; valeral; valeric aldehyde
3223	108-95-2	Phenol	Carbolic acid; hydroxybenzene; monohydroxybenzene; phenyl alcohol; phenyl hydroxide

See footnotes at end of table.

(Continued)

Flavoring substances with OSHA PELs and/or NIOSH RELs (Continued)

FEMA No.	CAS No.	Substance	Synonyms*
3233	100-42-5	Styrene	Ethenyl benzene; phenylethylene; styrene monomer; styrol; vinyl benzene
3241	75-50-3	Trimethylamine	N,N-Dimethylmethanamine; TMA
3326	67-64-1	Acetone	Dimethyl ketone; ketone propane; 2-propanone
3368	141-79-7	4-Methyl-3-penten-2-one	Isobutenyl methyl ketone; isopropylideneacetone; methyl isobutenyl ketone; mesityl oxide
3478	109-79-5	1-Butanethiol	Butanethiol; n-butanethiol; 1-mercaptobutane; n-butyl mercaptan
3537	108-83-8	2,6-Dimethyl-4-heptanone	Diisobutyl ketone; DIBK; sym-diisopropyl acetone; isovalerone; valerone
3589	108-46-3	Resorcinol	1,3-Benzenediol; m-benzenediol; 1,3-dihydroxybenzene; m-dihydroxybenzene; 3-hydroxyphenol; m-hydroxyphenol
3553	78-59-1	Isophorone	Isoacetophorone; 3,5,5-trimethyl-2-cyclohexenone; 3,5,5-trimethyl-2-cyclohexen-1-one
3616	108-98-5	Benzenethiol	Mercaptobenzene; phenyl mercaptan; thiophenol
3667	101-84-8	Diphenyl ether	Diphenyl oxide; phenoxy benzene; phenyl oxide; phenyl ether
3779	7783-06-4	Hydrogen sulfide	Hydrosulfuric acid; sewer gas; sulfuretted hydrogen
3909	108-94-1	Cyclohexanone	Anone; cyclohexyl ketone; pimelic ketone
3946	583-60-8	2-Methylcyclohexanone	o-Methylcyclohexanone

Adapted from Hallagan [2002].

*Synonyms from *Online NIOSH Pocket Guide to Chemical Hazards* (www.cdc.gov/niosh/npg/npgd0297.html).

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