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THE FLAVOR AND EXTRACT MANUFACTURERS ASSOCIATION OF THE UNITED STATES

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# Respiratory Health and Safety in the Flavor Manufacturing Workplace

## 2012 Update

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# Background

In August, 2004, FEMA published the report *Respiratory Health and Safety in the Flavor Manufacturing Workplace* containing information to help flavor manufacturers maintain safe workplaces. This web-based report updates and supplements the August, 2004, report. Many documents referred to in this report may be accessed through the links provided, while other copyrighted reports may be retrieved through the usual appropriate means.

Maintaining safe and healthy workplaces is a matter of utmost importance to FEMA and its members. FEMA consulted with experts on the development of this report and made extensive use of a wide variety of information resources. The application of the information in this report to flavor manufacturing workplaces is a function of the specific aspects of workplaces and the products handled and manufactured therein. Because of the unique nature of individual flavor manufacturing workplaces, the information in this report should be used only as a general guide. FEMA strongly urges users of this report to consult with appropriate experts regarding the circumstances relevant to respiratory health and safety in flavor manufacturing facilities.

Like the August, 2004, report, this report is not a standard but is intended to share information that flavor manufacturers may use as they choose. FEMA is not responsible for the use or non-use of the information, or any action or failure to act, in any specific workplace based on reliance on this report. It is the responsibility of users of this report to verify information as it applies to specific workplaces before acting and to comply with all relevant local, state, and federal laws and regulations.

The original 2004 report described three areas of emphasis for flavor manufacturers in maintaining the safest workplaces possible.

- Management and employee awareness through education and hazard communication
- Exposure assessment and control
- Medical surveillance

Since the 2004 report was published, important new information has become available on each of these areas of emphasis. This update provides a summary of important, new information but is not comprehensive in including every report or publication on any of the three subjects. Other information may be available, and FEMA urges flavor manufacturers to consult with appropriate experts in developing and implementing a respiratory health and safety program for their facilities.

# Workplace Safety Regulatory Requirements and Advice

**Federal**

Although there is no federal standard specifically for the flavor manufacturing industry, the industry is subject to a number of OSHA regulatory requirements. As OSHA has made clear in its National Emphasis Program for flavor manufacturing, the agency will rely heavily on the General Duty Clause of the Occupational

Safety and Health Act (Section 5(a)(1) of the Act) for broad authority over flavor manufacturing in general, and specifically for possible exposure to diacetyl. OSHA also implemented a National Emphasis Program for microwave popcorn manufacturing plants.

Flavor manufacturers should be familiar with, and comply with, the OSHA respirator standard. This standard remains the most common source of OSHA citations among flavor manufacturers.

The federal Hazard Communication Standard applies to many areas of flavor manufacturing. OSHA issued specific guidance in 2007 on hazard communication as it relates to diacetyl. OSHA has informally stated that this guidance also applies to 2,3-pentanedione, although OSHA has not yet amended the 2007 guidance to include this flavoring substance.

OSHA's confined space regulations may apply to some flavor manufacturers employing large vessels or tanks in their operations.

OSHA and NIOSH maintain web pages on flavorings-related lung disease. The OSHA page can be found at www.osha.gov/SLTC/flavoringlung/index.html. The NIOSH page can be found at www.cdc.gov/niosh/topics/flavorings/current-niosh.html. NIOSH also maintains a science blog on diacetyl and food flavorings at www.cdc.gov/niosh/blog/nsb111008_diacetyl.html.

Important information is available through the NIOSH program of Health Hazard Evaluations (HHEs). These are evaluations conducted by NIOSH staff on a wide variety of workplaces. Several types of facilities relevant to the flavor industry have been evaluated by NIOSH, including microwave popcorn manufacturing plants and flavor manufacturing facilities. Reports of NIOSH HHEs are available on the NIOSH website at www.cdc.gov/niosh/hhe/.

**California**

In 2006, the California Division of Occupational Safety and Health (Cal/OSHA) implemented the innovative program the Flavor Industry Safety and Health Evaluation Program (FISHEP) with the assistance of FEMA. This program resulted in workplace safety consultations by Cal/OSHA with flavor manufacturers operating in California. FISHEP also resulted in the completion of serial spirometry testing of several hundred California flavor manufacturing workers. FISHEP assisted California flavor manufacturers in maintaining safe workplaces and also provided important information used in the development and adoption of the California flavor manufacturing workplace regulations.

In 2010, California implemented a workplace safety regulation specifically for flavor manufacturing in California. The regulation contains a "1% cut-off" for diacetyl in compounded flavors and contains provisions related to flavoring substances considered as "alternatives" to diacetyl – acetoin, 2,3-pentanedione, diacetyl trimer, 2,3-hexanedione, and 2,3-heptanedione. The state's final statement of reasons explains the rationale for the regulations.

**Washington**

In 2008, the Washington State Department of Labor and Industries published an information sheet for restaurant owners and workers about diacetyl. The sheet states that it "provides information to cooks and restaurant workers about possibly harmful exposures to diacetyl during cooking."

# Occupational Exposure Guidelines

**Permissible Exposure Limits and Occupational Exposure Guidelines**

Few flavoring substances have permissible exposure limits (PELs) promulgated by OSHA. PELs have the force of regulation and are an important way that OSHA regulates workplace safety. Table 1 lists priority flavoring substances with OSHA PELs. Diacetyl and related substances such as 2,3-pentanedione and acetoin have not been assigned PELs by OSHA.

Three groups have published voluntary occupational exposure guidelines for diacetyl, and in one case for 2,3-pentanedione. While they don't have the regulatory authority of an OSHA PEL, these guidelines can be helpful to flavor manufacturers.

The American Conference of Government Industrial Hygienists (ACGIH) publishes threshold limit values (TLVs) and short-term exposure limits (STELs) for a wide variety of commercial substances including a small number of flavoring substances. In 2010, ACGIH proposed a TLV and STEL for diacetyl that were adopted in January, 2012. The ACGIH TLV for diacetyl is 0.01 ppm/8 hr. time-weighted average (TWA) and the STEL is 0.02 ppm/15 minutes.

In 2010, the non-governmental non-profit organization Toxicology Excellence for Risk Assessment (TERA) proposed an occupational exposure limit for diacetyl of 0.2 ppm/8 hr. TWA (Maier et al., 2010).

In its draft criteria document issued in 2011, NIOSH recommended exposure limits for diacetyl and 2,3-pentanedione of 5 ppb/8 hr. TWA and 9.3 ppb/8 hr. TWA, respectively. NIOSH also recommended short-tem exposure limits for each substance in the draft criteria document – 25 ppb/15 minutes for diacetyl and 31 ppb/15 minutes for 2,3-pentanedione.

The three groups publishing occupational exposure guidelines (TERA, ACGIH, and NIOSH) all employed different methods and data in arriving at their conclusions. Brosseau (2012) commented on the need for the application of consistent best practices in the development of occupational exposure guidelines.

# Management and Employee Awareness Through Education, Training and Hazard Communication

A variety of information resources are available for management from both OSHA and NIOSH on their websites on flavorings-related lung disease. The OSHA page can be found at www.osha.gov/SLTC/flavoringlung/index.html. The NIOSH page can be found at www.cdc.gov/niosh/topics/flavoring. Among the available resources are an OSHA worker alert published in 2010 and a NIOSH brochure for healthcare providers published in 2011.

Thorough education and communication among both management and employees of flavor manufacturers are critical to the success of any workplace health and safety program. Formal, mandatory hazard communication and training sessions assure that employees have the appropriate awareness of respiratory safety issues. Personnel in task areas that merit focus include:

- Personnel who blend and mix flavors in bulk quantities, especially those exposed to heated flavors, and the powder flavor and spray-dry manufacturing processes.
- Personnel who pack flavors (liquid or dry).
- Quality assurance personnel and flavorists who may have repeated exposure to flavors, even though exposure may be in smaller amounts.

**Hazard identification**

Over 2,700 chemically-defined flavoring substances and natural flavoring complexes are commonly used to formulate flavors. The U.S. Food and Drug Administration (FDA) is primarily responsible for the regulation of the addition of flavoring substances to food through several regulatory pathways (Hallagan and Hall, 2009). The vast majority of these materials have chemical and physical characteristics that would make it highly unlikely that they would pose a risk of respiratory injury in the workplace. Most of the materials are not very volatile and do not have a significant degree of reactivity. However, some low molecular weight chemically-defined flavoring substances may have sufficient volatility, and possibly reactivity, to pose a risk of respiratory injury when improperly handled. Table 1 contains a list of chemically-defined flavoring substances that may pose potential respiratory hazards when improperly handled.

The priority levels in Table 1 were assigned based on available inhalation exposure data in animals and humans, chemical structure, volatility, and volume of use. In many instances, data on one flavoring substance was used to evaluate the priority level for other structurally-related substances. In many cases, relevant inhalation exposure information is limited and, on occasion, is available for flavoring substances that have other, larger-scale industrial uses. The assignment of priority levels required the application of significant judgment and also took into account anecdotal information provided by workers in the flavor industry who shared their valuable experience related to the handling of flavoring substances.

Since the original edition of this report was published in 2004, new information has become available on substances structurally-related to diacetyl resulting in their addition to the table as high priority substances. These substances include 2,3-pentanedione, 2,3-hexandione, 3,4-hexanedione, 2,3-heptandione, and diacetyl trimer. A few substances were reassigned from high priority to low priority based on new information. No substances were removed from Table 1.

Table 1 contains updated information on each flavoring substance from the FEMA Poundage Survey. Data from the 1995, 2005, and 2010 surveys are included and represent the amount of each flavoring substance estimated to “disappear” into the U.S. food supply in a given year. This information allows a rough estimate on the trends of use for the listed substances.

**Hazard communication - MSDSs**

Clear communication of potential hazards is of critical importance. The OSHA Hazard Communications Standard establishes a minimum for hazard communication through its material safety data sheet (MSDS) requirements.

The development and provision of MSDSs is an individual company obligation. FEMA does not, and has never, compiled or published MSDSs, or reviewed or approved company MSDSs. FEMA has assisted members in meeting their hazard communications obligations only through serving as a "library" for information.

FEMA members have access to the Flavor and Fragrance Ingredient Data Sheet (FFIDS) program that provides information on workplace hazards and that can be used as one source of information to formulate MSDSs on flavoring substances.

Another resource available to FEMA members is the IFRA/IOFI GHS Labeling Manual issued jointly by the International Fragrance Association (IFRA) and the International Organization of the Flavor Industry (IOFI). FEMA is a member of IOFI. The Labeling Manual provides information on the harmonization of hazard statements for hazard communications purposes according to the Globally Harmonized System of Classification and Labeling of Chemicals (the "GHS"). OSHA published its final rule adopting the GHS in March 2012.

**Hazard communication - labeling**

In addition to the various types of labeling requirements under relevant regulations, the labeling of bulk flavors may also be appropriate in certain circumstances to alert workers to potential respiratory hazards. It is recommended that the following bulk flavors bear a label using the language described below, or language that conveys a similar warning.

- Containers of "high priority" neat substances listed in Table 1 such as diacetyl, 2,3-pentanedione and acetaldehyde.
- Containers of compounded flavors (liquid and dry or powdered) or natural flavoring complexes that contain "high priority" flavoring substances in concentrations >1.0%.
- Any compounded flavors (liquid and dry or powdered) containing any flavoring substances listed in Table 1 in any concentrations if the compounded flavor or any of its individual flavoring substances will be heated during processing.

**WARNING – This flavor may pose an inhalation hazard if improperly handled. Please contact your workplace safety officer before opening and handling, and read the MSDS. Handling of this flavor that results in inhalation of fumes, especially if the flavor is heated, may cause severe adverse health effects.**

It is recommended that the following bulk flavors bear a label using the language described below, or language that conveys a similar warning.

- Containers of neat "low priority" chemically-defined substances as listed in Table 1.
- Containers of natural flavoring complexes known to contain chemically-defined flavoring substances listed in Table 1.
- Containers of compounded flavors (liquid and dry or powdered) containing "high priority" chemically-defined substances at concentrations <1.0%, or "low priority" chemically-defined substances at any level.

**ATTENTION - Safe flavors can be used in an unsafe manner. Please contact your workplace safety officer before opening and handling this flavor, and read the MSDS.**

Flavor manufacturers and suppliers cannot in all instances know how their customer will use a flavoring material. In many instances, the customer chooses to keep information related to how they will use a flavoring material confidential to protect valuable trade secret information related to their products. In other instances, customers may communicate to a supplier how they plan to use a flavor but then modify their plans. The warning statements suggested in this section provide a means for flavor manufacturers to assure their customers receive helpful information related to the safe handling and use of flavors.

Important resources on the subject of management and employee awareness include:

- The OSHA Hazard Communications Standard.
- OSHA GHS Implementation Program.
- Hazard Communication Guidance for Diacetyl and Food Flavorings Containing Diacetyl (OSHA, 2007).
- Occupational Exposure to Flavoring Substances: Health Effects and Hazard Control (OSHA, 2010).
- OSHA National Emphasis Program for Facilities that Manufacture Food Flavorings Containing Diacetyl (OSHA, 2011).

# Exposure Assessment and Control

**Assessment of potential exposures**

Environmental monitoring is a necessary component of a sound respiratory health and safety program. Monitoring at regular intervals can provide valuable information on potential exposures. In addition to monitoring for the presence of certain vapors in air, monitoring of particulates, when appropriate, should also be conducted if reliable methods are available. A critical issue in any monitoring program is identifying the appropriate substances to monitor. NIOSH has focused on diacetyl and 2,3-pentanedione and provides a thorough discussion of analytical methods and sampling in the draft report *Occupational Exposure to Diacetyl and 2,3-Pentanedione* (NIOSH, 2011). Also relevant are reports by Cox-Gansler et al. (2011) and Day et al. (2011).

**Exposure control**

Flavor manufacturing facilities vary greatly in size, structure, age, manufacturing technologies employed, flavoring substances stocked and handled, types of flavors manufactured, and many other characteristics. Manufacturing processes may range from simple blending and packaging to more complicated processes that include repeated heating of flavoring substances that are mixed and heated again, extraction at room temperature and with heat, and other processes that may result in significant opportunities for exposure.

Some facilities have extensive automated processes that minimize opportunities for exposure while others have little automation and rely on workers manipulating large quantities of flavors and other materials by hand during the formulation and packing processes. Because of this great variability, "one size fits all" solutions to material handling strategies and engineering controls is inappropriate. However, a number of basic principles can greatly reduce opportunities for hazardous exposures.

**Product substitution**

Awareness that specific substances are hazardous often results in the application of a simple industrial hygiene strategy – product substitution. Product substitution may be employed when it is known that a substance is hazardous and can be replaced with one that isn't. The unique nature of the flavor imparted by certain substances, many of which are naturally occurring constituents of food, makes it difficult to identify substitutes that are effective.

In 2010 OSHA published a "Worker Alert" on diacetyl and substitutes noting that "some diacetyl substitutes may also cause harm." The Alert stated, "Diacetyl substitutes that have not been proven to be safe include diacetyl trimer, 2,3-hexanedione, 2,3-heptanedione, and 2,3-pentanedione." In January, 2011, NIOSH requested information on flavoring substances that may be used as substitutes for diacetyl (76 Fed. Reg. 1434. 10 January 2011). FEMA provided information to NIOSH on six flavoring substances that it was aware of that may serve as substitutes for diacetyl:

- Four alpha-diketone substances: 2,3-pentanedione, 2,3-hexanedione, 3,4-hexanedione, and 2,3-heptanedione.
- Two other related substances: acetoin and diacetyl trimer.

NIOSH published results from environmental monitoring at a microwave popcorn production plant focusing on the possible presence of "diacetyl substitutes" (Boylstein, 2012).

**Heating of flavors**

Heating of flavors is of particular concern with regard to potential hazardous exposures. Heating will increase volatility and greatly increase air concentrations of flavoring substances. Mixing of heated flavors should be conducted in closed vessels with local ventilation. Workers should not open heated vessels to conduct visual inspections in such a way as to create an opportunity for exposure. In instances when workers must work near open vessels that are heated and cannot be closed or do not have local ventilation, their exposures should be promptly evaluated by environmental sampling. If exposures are elevated then the proper personal protective equipment should be employed.

**Facility structure and organization**

Opportunities for exposure can be greatly decreased by segregating functions that involve the handling of flavors from functions that do not. For example, a flavor compounding, packing, or shipping area should not share space with a sales office. Flavor production areas should be separate from non-production areas and they should not share the same air handler.

**Ventilation**

Flavoring substances and mixtures, whether liquid or dry, must be handled in such a way as to minimize the creation of airborne aerosols or particulate matter. This means that mixing, blending, and other physical manipulation activities should be performed in closed systems when possible. When systems must remain open, local ("spot") ventilation (e.g. "elephant trunks") should be used. Fume hoods are commonly used in research and development laboratories. Dilution through general room ventilation seldom results in exposure reduction unless extremely high volumes of air are circulated.

**Material handling – flavor compounding and packing activities**

Simple flavor compounding activities such as mixing or pouring can result in significant exposures. In most instances, mixing of liquid and dry flavors should be conducted in fully or partially closed vessels with local ventilation. Opportunities for the generation of airborne particles and aerosols should be minimized.

Proper pouring techniques for liquid and dry flavors can greatly reduce opportunities for exposure. For liquid flavoring substances, techniques can be adopted that pipe material into mixing vessels so that workers do not have to pour. In some instances it is appropriate to pipe in liquids below the surface of solutions in vessels to minimize splashing. This is particularly important for volatile substances.

For dry and powdered flavors, pouring should be conducted in such a way that the generation of airborne particulates is minimized. Simple, proper pouring techniques such as pouring slowly close to the mixing vessel can greatly minimize airborne particulates. Mixing ingredients in an order in which dry ingredients are added last to liquid mixtures also can minimize particulate generation. Local exhaust is the most effective control for these operations. Systems can be designed that will allow easy pouring and at the same time control exposures.

Packaging activities can result in significant opportunities for exposure, especially when dry flavors are filled into bags, boxes, or drums under pressure. Closed systems should be used when possible. But unless there is an unusually high degree of automation, workers will have opportunities for exposure as filled containers must be replaced with empty ones. The use of personal protective equipment may then need to be considered to minimize exposure.

**Material storage**

Flavoring substances that are volatile should be stored in cooled storage areas. Substances such as acetaldehyde are often stored in cooled rooms, and are often also used in flavor manufacture in a cooled state. Liquid and dry and powdered flavors should ideally be stored in store-rooms with their own air handler that has minimum recirculation. In some instances, flavor facilities have negative air flow in storage areas to reduce opportunities for exposure.

**Cleaning of vessels and work areas**

Cleaning of process vessels that contained liquid flavors or viscous mixtures, or work areas with spilled material, especially with steam or heated water, may create opportunities for exposure to flavoring substances. Similarly, cleaning vessels or areas used to manufacture or mix powdered flavors with compressed air may also result in airborne particulates.

It is important that cleaning activities be conducted in a manner that does not result in significant air concentrations of flavors and other materials present in the vessel. Cleaning areas should be isolated and contained to prevent the dissemination of airborne flavors. Automated cleaning processes will greatly reduce opportunities for exposure. In some instances, the most effective way to protect workers responsible for cleaning activities will be to use respirators.

It is also important that adequate care be exercised if workers are to enter or partially enter equipment in order to clean it. In addition to concerns about possible respiratory exposures, in some instances, cleaning activities involving vessel entry may be subject to the requirements of OSHA's confined space regulations (29 CFR 1910.146).

**Personal respiratory protection**

The implementation of appropriate process and engineering controls is preferable to simply providing employees with personal respiratory protection. However, respirators do have a role in many respiratory health and safety programs. Critical to their success is the selection of the proper respirator for the conditions present in a given facility, the proper fit of that respirator to the person using it, and the training in its use, maintenance, and storage. OSHA also requires that employees wearing most types of respirators undergo medical clearance prior to their use.

In terms of specific duty requirements relevant to protection against respiratory hazards, OSHA regulations require that personal protective equipment must be provided to employees whenever necessary to address chemical or other hazards which are "capable of causing injury or impairment in the function of any part of the body through absorption, inhalation or physical contact." Under OSHA's Respiratory Protection Standard, the "primary objective shall be to prevent atmospheric contamination." Where, however, that is not feasible through engineering and process controls, respirators shall be used. The regulations contain a range of requirements, including the proper selection of respirators, standard procedures for use, training of employees, respirator maintenance, and other safety measures. The standard and relevant background information were published in the *Federal Register* notice announcing the standard (63 Fed. Reg. 1152. 8 January 1998).

Important resources on the subjects of exposure assessment and control include:

- Diacetyl exposures in the flavor manufacturing industry (Martyny et al., 2008).
- Evaluation of a local exhaust ventilation system for controlling exposures during liquid flavor production (Dunn et al., 2008).
- Occupational Exposure to Flavoring Substances: Health Effects and Hazard Control (OSHA, 2010).
- OSHA National Emphasis Program for Facilities that Manufacture Food Flavorings Containing Diacetyl (OSHA, 2011).
- OSHA National Emphasis Program for Microwave Popcorn Processing Plants (OSHA, 2011).
- Draft Criteria Document - Occupational Exposure to Diacetyl and 2,3-Pentanedione (NIOSH, 2011).
- Occupational lung disease risk and exposure to butter-flavoring chemicals after implementation of controls at a microwave popcorn plant (Kanwal et al., 2011).

**Medical surveillance**

Medical surveillance is a key component of an effective respiratory health and safety program in the flavor industry. This is especially the case when it is difficult to identify a specific causative agent for an observed effect and when symptoms and/or lung function abnormalities may be the first clue to an exposure-related problem. Appropriate medical surveillance can identify health issues before progression to severe illness occurs and when opportunities for reducing or eliminating exposure exist.

Medical surveillance should include an evaluation at the time of hire and at least annually thereafter. The exam should include both a medical and occupational history and a pulmonary function component. Spirometry is a simple and inexpensive way to monitor pulmonary function status and should be included in the exam at hire and in follow-up exams thereafter. It is important that spirometry testing follow the most recent American Thoracic Society guidelines for accurate testing.

A sound medical surveillance program will facilitate the identification of respiratory symptoms and lung function abnormalities. As reported by NIOSH, some workers in microwave popcorn manufacturing facilities, and in a few flavor manufacturing facilities, exhibited findings of fixed airway obstruction manifested by symptoms of cough (often without the production of phlegm) and shortness of breath after exertion as well as spirometric abnormalities (e.g. decreased FEV-1, a parameter of airflow). Frequent or persistent symptoms of eye, nose, throat or skin irritation have also been reported by NIOSH in some affected workers. A plan should be in place to refer employees for further medical follow-up and evaluation if such symptoms and lung function abnormalities are identified in the surveillance examinations or if there are significant unexplained declines in employee lung function as measured by periodic spirometry.

It is particularly important to note that bronchiolitis obliterans, a very serious lung disease, has been implicated in cases of respiratory illness seen in microwave popcorn manufacturing plants and in flavor manufacturing facilities. Early detection of symptoms and spirometric abnormalities through a medical surveillance program will allow workers to seek timely follow-up and may prevent progression of disease. Early detection is especially important with bronchiolitis obliterans because the disease is difficult to treat.

Important information resources on the subject of medical surveillance include:

Establishing a quality medical surveillance program in your flavor company. Rose C. and Sells T. National Jewish Health. Presentation at the conference "Respiratory Health and Safety in the Flavor Manufacturing Workplace – A Training Session for Flavor Plant Staff." FEMA. 2005.

Occupational Exposure to Flavoring Substances: Health Effects and Hazard Control (OSHA, 2010).

Occupational Exposure to Diacetyl and 2,3-Pentanedione (NIOSH, 2011).

# Developing a Respiratory Safety Program for Flavor Manufacturing Facilities

FEMA and a number of its members have worked with National Jewish Health in Denver, Colorado (NJH) through Cecile Rose, M.D., M.P.H., and Mike VanDyke, Ph.D., C.I.H. Dr. Rose is an expert in pulmonary diseases, and Dr. VanDyke is a certified industrial hygienist. Both have worked extensively with the flavor industry and have significant experience with flavors and flavor manufacturing. Other sources of expert assistance include occupational medicine physicians and industrial hygiene consultants located in the communities where flavor manufacturing facilities are located. Among other sources of information, consultants can be identified through the consultant directory maintained by the American Industrial Hygiene Association (www.aiha.org).

National Jewish Health was awarded a grant by OSHA in late 2011 to conduct training on respiratory health and safety programs for flavor manufacturers. NJH has been provided funding by OSHA to train 500 people working in flavor manufacturing. The focus is expected to be on workers employed in direct flavor manufacturing, i.e. workers responsible for handling and formulating flavorings. Please contact John Hallagan of FEMA for information (202.331.2333; Hondobear@aol.com).

# References and Other Relevant Publications

Since 2004, a number of reports have been published relevant to the safety of possible exposure to flavoring substances in the workplace and other aspects of respiratory health and safety in flavor manufacturing. References for publications cited in the body of this report may be found in this list in addition to publications not cited but of interest.

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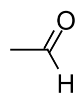
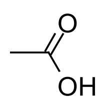
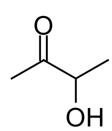
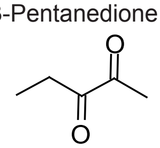
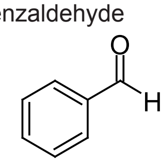
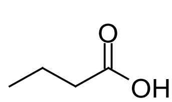
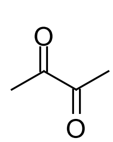
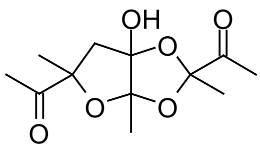
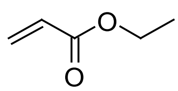
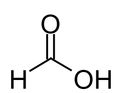
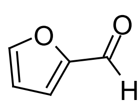
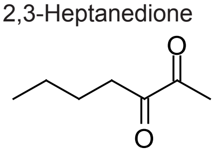
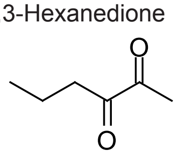
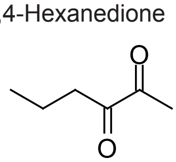
VanRooy F.G.B.G.J., Smit L.A.M., Houba R., Zaat V.A.C., Rooyackers J.M. and Heederik D.J.J. A cross sectional study on lung function and respiratory symptoms among chemical workers producing diacetyl for food flavourings. *Occup Environ Med,* 66,105. 2009.

Zviely M. Molecule of the month: 2,3-pentanedione. *Perfumer & Flavorist.* 34(7), 20. 2009.

## TABLE 1

| *FEMA* | *CAS* | *Principal Name* | *Molecular Weight* | *Calculated Vapor PressureValue* | *PEL Data*[a,b] | *Reported Poundage*[c] *(lbs)* |
|---|---|---|---|---|---|---|
| **High Priority** | | | | | | |
| 2003 | 75-07-0 | Acetaldehyde  | 44.05 | 759 mm Hg 20 °C<br>910 mm Hg 25 °C | OSHA PEL - TWA 200 ppm, 360 mg/m3 | 1995: 321,000<br>2005: 70,200<br>2010: 59,000 |
| 2006 | 64-19-7 | Acetic acid  | 60.05 | 12.9 mm Hg 20 °C<br>17.2 mm Hg 25 °C | OSHA PEL - TWA 10 ppm, 25 mg/m3 | 1995: 310,000<br>2005: 271,000<br>2010: 373,000 |
| 2008 | 513-86-0 | Acetoin  | 88.11 | 1.36 mm Hg 20 °C<br>2 mm Hg 25 °C | NA | 1995: 116,000<br>2005: 133,000<br>2010: 150,000 |
| 2841 | 600-14-6 | 2,3-Pentanedione  | 100.12 | 23.8 mm Hg 20 °C<br>31.1 mm Hg 25 °C | NIOSH REL- TWA 9.3 ppb NIOSH STEL 31 ppb | 1995: 2,600<br>2005: 4,590<br>2010: 38,000 |
| 2127 | 100-52-7 | Benzaldehyde  | 106.13 | 0.705 mm Hg 20 °C<br>1.01 mm Hg 25 °C | NA | 1995: 603,000<br>2005: 1,410,000<br>2010: 578,000 |
| 2221 | 107-92-6 | Butyric Acid  | 88.11 | 1.5 mm Hg 20 °C<br>2.11 mm Hg 25 °C | NA | 1995: 180,000<br>2005: 130,000<br>2010: 229,000 |
| 2370 | 431-03-8 | Diacetyl  | 86.09 | 55 mm Hg 20 °C<br>70.2 mm Hg 25 °C | NIOSH REL- TWA 5 ppb<br>NIOSH STEL 25 ppb<br>TERA OEL- TWA 0.2 ppm | 1995: 211,000<br>2005: 228,000<br>2010: 85,000 |

**CONTINUED**

| FEMA | CAS | Principal Name | Molecular Weight | Calculated Vapor PressureValue | PEL Data[a,b] | Reported Poundage[c] (lbs) |
|---|---|---|---|---|---|---|
| 4303 | 18114-49-3 | Diacetyl trimer  | 258.27 | NA | See Diacetyl | 1995: NA<br>2005: NA<br>2010: 0 |
| 2418 | 140-88-5 | Ethyl acrylate  | 100.12 | 29.4 mm Hg 20 °C<br>38.4 mm Hg 25 °C | PEL - Skin TWA 25 ppm, 100 mg/m3 | 1995: 11<br>2005: 3<br>2010: 59 |
| 2487 | 64-18-6 | Formic Acid  | 46.03 | 27.4 mm Hg 20º C<br>35.9 mm Hg 25 °C | OSHA PEL - TWA 5 ppm, 9 mg/m3 | 1995: 20,600<br>2005: 7,150<br>2010: 9,500 |
| 2489 | 98-01-1 | Furfural  | 96.09 | 1.65 mm Hg 20 °C<br>2.32 mm Hf 25 °C | OSHA PEL - Skin TWA 5 ppm, 20 mg/m3 | 1995: 7,710<br>2005: 8,240<br>2010: 9,300 |
| 2543 | 96-04-8 | 2,3-Heptanedione  | 128.17 | 0.785 mm Hg 20 °C<br>1.11 mm Hg 25 °C | NA | 1995: 100<br>2005: 78<br>2010: 120 |
| 2558 | 3848-24-6 | 2,3-Hexanedione  | 114.14 | 2.11 mm Hg 20 °C<br>2.93 mm Hg 25 °C | NA | 1995: 620<br>2005: 400<br>2010: 2,500 |
| 3168 | 4437-51-8 | 3,4-Hexanedione  | 114.14 | 9.2 mm Hg 20 °C<br>12.3 mm Hg 25 °C | NA | 1995: 39<br>2005: 13<br>2010: 200 |

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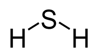
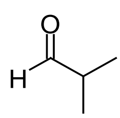
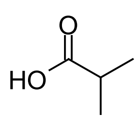
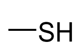
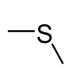
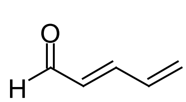
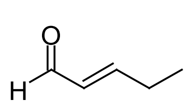
| FEMA | CAS | Principal Name | Molecular Weight | Calculated Vapor PressureValue | PEL Data[a,b] | Reported Poundage[c] (lbs) |
|---|---|---|---|---|---|---|
| 3779 | 7783 - 06 4 | Hydrogen sulfide  | 34.08 | 3.81 x 10-9 mm Hg 25 °C | OSHA PEL - Exposures shall not exceed 20 ppm (ceiling) with the following exception: if no other measurable exposure occurs during the 8-hour work shift, exposures may exceed 20 ppm, but not more than 50 ppm (peak), for a single time period up to 10 minutes NIOSH REL - 10 ppm, ceiling limit 15 mg/m3 (10 minutes) | 1995: 3<br>2005: 210<br>2010: 22 |
| 2220 | 78-84-2 | Isobutyraldehyde  | 72.11 | 131 mm Hg 20 °C<br>164 mm Hg 25 °C | NA | 1995: 1,100<br>2005: 1,010<br>2010: 1,400 |
| 2222 | 79-31-2 | Isobutyric acid  | 88.11 | 2.35 mm Hg 20 °C<br>3.27 mm Hg 25 °C | NA | 1995: 8,750<br>2005: 6,840<br>2010: 8,700 |
| 2716 | 74-93-1 | Methyl mercaptan  | 48.11 | 1.28 X 103mm Hg 20 °C<br>1510 mm Hg 25 °C | OSHA PEL - ceiling limit TWA 10 ppm, 20 mg/m3 | 1995: 52<br>2005: 240<br>2010: 400 |
| 2746 | 75-18-3 | Methyl sulfide  | 62.13 | 391 mm Hg 20 °C<br>479 mm Hg 25 °C | NA | 1995: 8,200<br>2005: 22,900<br>2010: 17,000 |
| 3217 | 764-40-9 | 2,4-Pentadienal  | 82.1 | 20 mm Hg 25 °C | NA | 1995: 0<br>2005: 0<br>2010: 0 |
| 3218 | 764-39-6 | 2-Pentenal  | 84.12 | 13.9 mm Hg 20 °C<br>18.5 mm Hg 25 °C | NA | 1995: 3<br>2005: 24<br>2010: 54 |

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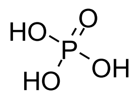
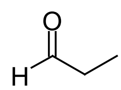
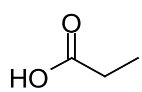
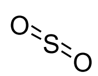
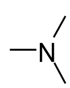
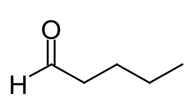
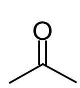
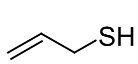
| FEMA | CAS | Principal Name | Molecular Weight | Calculated Vapor PressureValue | PEL Data[a,b] | Reported Poundage[c] (lbs) |
|---|---|---|---|---|---|---|
| 2900 | 7664-38-2 | Phosphoric acid  | 67.02 | 6.09 x 10-11 mm Hg 25 ºC | OSHA PEL - TWA 1 mg/ m3 | 1995: 4,840,000<br>2005: 5,780,000<br>2010: 423,000 |
| 2923 | 123-38-6 | Propionaldehyde  | 58.08 | 256 mm Hg 20 ºC<br>317 mm Hg 25 ºC | NA | 1995: 3,870<br>2005: 590<br>2010: 700 |
| 2924 | 79-09-4 | Propionic acid  | 74.08 | 4.41 mm Hg 20 ºC<br>6.04 mm Hg 25 ºC | NIOSH REL- TWA 10 ppm, 30 mg/m3 | 1995: 44,400<br>2005: 24,500<br>2010: 33,000 |
| 3039 | 9/5/7446 | Sulfur dioxide  | 64.06 | 2600 mm Hg 25 ºC | OSHA PEL - TWA 5 ppm, 13 mg/m3 | 1995: 4,100<br>2005: 470<br>2010: 330 |
| 3241 | 75-50-3 | Trimethylamine  | 59.11 | 1680 mm Hg 25 ºC | NIOSH REL - TWA 10 ppm; STEL 15 ppm | 1995: 870<br>2005: 640<br>2010: 3200 |
| 3098 | 110-62-3 | Valeraldehyde  | 86.13 | 25.1 mm Hg 20 ºC<br>32.9 mm Hg 25 ºC | NOSH REL -TWA 50 ppm, 176 mg/m3 | 1995: 140<br>2005: 150<br>2010: 1600 |
| **Low Priority** | | | | | | |
| 3326 | 67-64-1 | Acetone  | 58.08 | 249 mm Hg 25 ºC | OSHA PEL - TWA 1000 ppm, 2400 mg/m3 | 1995: 400<br>2005: 360<br>2010: 370 |
| 2035 | 870-23-5 | Allyl mercaptan  | 74.14 | 161 mm Hg 25 ºC | NA | 1995: 1<br>2005: 1<br>2010: 1 |

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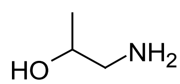
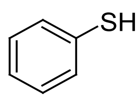
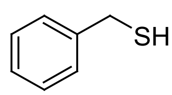
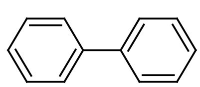
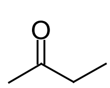
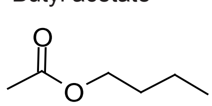
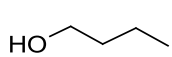
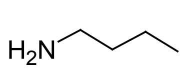
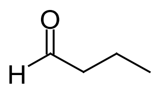
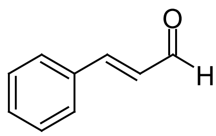
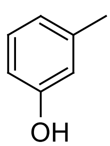
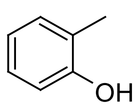
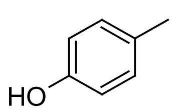
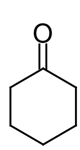
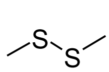
| FEMA | CAS | Principal Name | Molecular Weight | Calculated Vapor PressureValue | PEL Data[a,b] | Reported Poundage[c] (lbs) |
|---|---|---|---|---|---|---|
| 2053 | 12124-99-1 | Ammonium sulfide<br>$(NH_4)_2S$ | 68.15 | 9.2 x 10-15 mm Hg 25 ºC | NA | 1995: 660<br>2005: 600<br>2010: 1300 |
| 3965 | 78-96-6 | 1-Amino-2-propanol<br> | 75.13 | 0.768 mm Hg 25 ºC | NA | 1995: NA<br>2005: 0<br>2010: 0 |
| 3616 | 108-98-5 | Benzenethiol<br> | 110.18 | 1.63 mm Hg 25 ºC | "NIOSH REL-ceiling limit TWA 0.1 ppm, 0.5 mg/m3 (15 minutes)" | 1995: 4<br>2005: 1<br>2010: 3800 |
| 2147 | 100-53-8 | Benzyl mercaptan<br> | 124.21 | 0.3 mm Hg 20 ºC<br>0.474 mm Hg 25 ºC | NA | 1995: 0<br>2005: 0.1<br>2010: 0.1 |
| 3129 | 92-52-4 | Biphenyl<br> | 154.21 | 0.00419 mm Hg 20 ºC<br>0.00749 mm Hg 25 ºC | OSHA PEL - TWA 0.2 ppm, 1mg/m3 | 1995: 0<br>2005: 0<br>2010: 0 |
| 2170 | 78-93-3 | 2-Butanone<br> | 72.11 | 77.9 mm Hg 20 ºC<br>98.5 mm Hg 25 ºC | OSHA PEL - TWA 200 ppm, 590 mg/m3 | 1995: 530<br>2005: 960<br>2010: 1200 |
| 2174 | 123-86-4 | Butyl acetate<br> | 116.16 | 8.85 mm Hg 20 ºC<br>11.9 mm Hg 25 ºC | OSHA PEL- TWA 150 ppm, 710 mg/m3 | 1995: 26,300<br>2005: 36,700<br>2010: 37,000 |
| 2178 | 71-36-3 | Butyl Alcohol<br> | 74.12 | 5.49 mm Hg 20 ºC<br>7.78 mm Hg 25 ºC | OSHA PEL - TWA 100 ppm, 300 mg/m3 | 1995: 13,300<br>2005: 6,580<br>2010: 7,200 |
| 3130 | 109-73-9 | Butylamine<br> | 73.14 | 71 mm Hg 20 ºC<br>94.7 mm Hg 25 ºC | OSHA PEL - TWA 5 ppm, 15 mg/m3 ceiling; skin | 1995: 0<br>2005: 0<br>2010: 0 |

**CONTINUED**

| *FEMA* | *CAS* | *Principal Name* | *Molecular Weight* | *Calculated Vapor PressureValue* | *PEL Data*[a,b] | *Reported Poundage*[c] *(lbs)* |
|---|---|---|---|---|---|---|
| 2219 | 123-72-8 | Butyraldehyde  | 72.11 | 84.9 mm Hg 20 ºC<br>108 mm Hg 25 ºC | NA | 1995: 340<br>2005: 240<br>2010: 100 |
| 2286 | 104-55-2 | Cinnamaldehyde  | 132.16 | 0.0214 mm Hg 20 ºC<br>0.0337 mm Hg 25 ºC | NA | 1995: 993,000<br>2005: 683,000<br>2010: 421,000 |
| 3530 | 108-39-4 | m-Cresol  | 108.14 | 0.109 mm Hg 20 ºC<br>0.167 mm Hg 25 ºC | OSHA PEL - Skin TWA 5 ppm, 22 mg/m3. OSHA standard is for all cresols combined under CAS Number 1319-77-3 (Federal Register 7/5/89). | 1995: 0<br>2005: 0.1<br>2010: 0 |
| 3480 | 95-48-7 | o-Cresol  | 108.14 | 0.15 mm Hg 20 ºC<br>0.25 mm Hg 25 ºC | OSHA PEL - Skin TWA 5 ppm, 22 mg/m3. OSHA standard is for all cresols combined under CAS Number 1319-77-3 (Federal Register 7/5/89). | 1995: 1<br>2005: 0.1<br>2010: 2 |
| 2337 | 106-44-5 | p-Cresol  | 108.14 | 0.073 mm Hg 20 ºC<br>0.124 mm Hg 25 ºC | OSHA PEL - Skin TWA 5 ppm, 22 mg/m3. OSHA standard is for all cresols combined under CAS Number 1319-77-3 (Federal Register 7/5/89). | 1995: 17<br>2005: 170<br>2010: 810 |
| 3909 | 108-94-1 | Cyclohexanone  | 98.15 | 2.94 mm Hg 20 ºC<br>4.04 mm Hg 25 ºC | OSHA PEL - TWA 50 ppm, 200 mg/m3 | 1995: NA<br>2005: 0<br>2010: 0 |
| 3536 | 624-92-0 | Dimethyl disulfide  | 94.2 | 18.5 mm Hg 20 ºC<br>24.5 mm Hg 25 ºC | NA | 1995: 4,170<br>2005: 32<br>2010: 3,600 |

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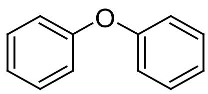
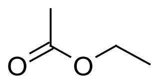
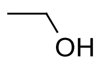
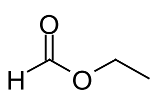
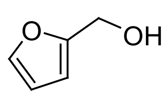
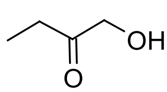
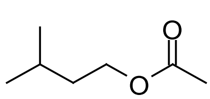
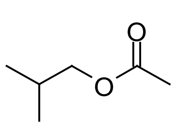
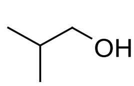
| FEMA | CAS | Principal Name | Molecular Weight | Calculated Vapor PressureValue | PEL Data[a,b] | Reported Poundage[c] (lbs) |
|---|---|---|---|---|---|---|
| 3667 | 101-84-8 | Diphenyl ether  | 170.21 | 0.00973 mm Hg 20 ºC<br>0.017 mm Hg 25 ºC | OSHA PEL - Vapor TWA 1ppm, 7 mg/m3 | 1995: 86<br>2005: 280<br>2010: 4,000 |
| 2414 | 141-78-6 | Ethyl acetate  | 88.11 | 77 mm Hg 20 ºC<br>98.3 mm Hg 25 ºC | OSHA PEL - TWA 400 ppm, 1400 mg/m3 | 1995: 462,000<br>2005: 514,000<br>2010: 460,000 |
| 2419 | 64-17-5 | Ethyl alcohol  | 46.07 | 45.3 mm Hg 20 ºC<br>60.9 mm Hg 25 ºC | OSHA PEL - TWA 1000 ppm, 1900 mg/m3 | 1995: 23,500,000<br>2005: 30,600,000<br>2010: 20,200,000 |
| 2434 | 109-94-4 | Ethyl formate  | 74.08 | 198 mm Hg 20 ºC<br>246 mm Hg 25 ºC | OSHA PEL - TWA 100 ppm, 300 mg/m3 | 1995: 18,600<br>2005: 21,400<br>2010: 19,000 |
| 2491 | 98-00-0 | Furfuryl alcohol  | 98.1 | 0.267 mm Hg 20 ºC<br>0.409 mm Hg 25 ºC | OSHA PEL - TWA 50 ppm, 200 mg/m3 | 1995: 410<br>2005: 560<br>2010: 1,000 |
| 3173 | 5077-67-8 | 1-Hydroxy-2-butanone  | 88.11 | 0.768 mm Hg 25 ºC | NA | 1995: 0<br>2005: 0<br>2010: 0 |
| 2055 | 123-92-2 | Isoamyl acetate  | 130.19 | 4.13 mm Hg 20 ºC<br>5.67 mm Hg 25 ºC | OSHA PEL - TWA 100 ppm, 525 mg/m3 | 1995: 441,000<br>2005: 372,000<br>2010: 270,000 |
| 2175 | 110-19-0 | Isobutyl acetate  | 116.16 | 13.7 mm Hg 20 ºC<br>18.3 mm Hg 25 ºC | OSHA PEL - TWA 150 ppm, 700 mg/m3 | 1995: 35,600<br>2005: 39,300<br>2010: 60,000 |
| 2179 | 78-83-1 | Isobutyl alcohol  | 74.12 | 9.55 mm Hg 20 ºC<br>13.4 mm Hg 25 ºC | OSHA PEL - TWA 100 ppm, 300 mg/m3 | 1995: 27,700<br>2005: 20,000<br>2010: 8,800 |

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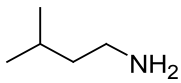
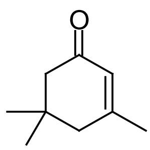
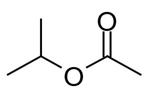
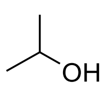
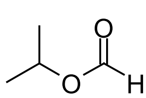
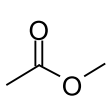
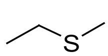
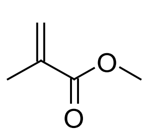
| FEMA | CAS | Principal Name | Molecular Weight | Calculated Vapor PressureValue | PEL Data[a,b] | Reported Poundage[c] (lbs) |
|---|---|---|---|---|---|---|
| 3219 | 107-85-7 | Isopentylamine  | 87.17 | 40 mm Hg 20 ºC<br>44.5 mm Hg 25 ºC | NA | 1995: 1<br>2005: 0<br>2010: 0.4 |
| 3553 | 78-59-1 | Isophorone  | 138.2 | 0.169 mm Hg 20 ºC<br>0.249 mm Hg 25 ºC | OSHA PEL - TWA 25 ppm, 140 mg/m3 | 1995: 2<br>2005: 220<br>2010: 3 |
| 2926 | 108-21-4 | Isopropyl acetate  | 102.13 | 47.1 mm Hg 20 ºC<br>60.8 mm Hg 25 ºC | OSHA PEL - TWA 250 ppm, 950 mg/m3 | 1995: 1,180<br>2005: 70<br>2010: 190 |
| 2929 | 67-63-0 | Isopropyl alcohol  | 60.1 | 36.7 mm Hg 20 ºC<br>49.6 mm Hg 25 ºC | OSHA PEL - TWA 400 ppm, 980 mg/m3 | 1995: 176,000<br>2005: 14,300<br>2010: 96,000 |
| 2944 | 625-55-8 | Isopropyl formate  | 88.11 | 110 mm Hg 20 ºC<br>142 mm Hg 25 ºC | NA | 1995: 0<br>2005: 0<br>2010: 0 |
| 2676 | 79-20-9 | Methyl acetate  | 74.08 | 40.6 mm Hg 20 ºC<br>52.7 mm Hg 25 ºC | OSHA PEL - TWA 200 ppm, 610 mg/m3 | 1995: 1,060<br>2005: 1,370<br>2010: 1,500 |
| 3860 | 624-89-5 | Methyl ethyl sulfide  | 76.16 | 150 mm Hg 25 ºC | NA | 1995: NA<br>2005: 0<br>2010: 0 |
| 4002 | 80-62-6 | Methyl methacrylate  | 100.12 | 36.7 mm Hg 25 ºC | OSHA PEL - TWA 100 ppm, 410 mg/m3 | 1995: NA<br>2005: 0<br>2010: 0 |

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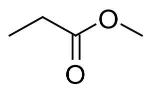
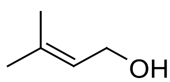
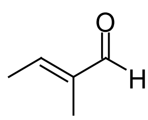
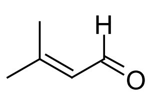
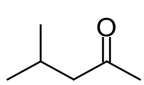
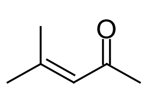
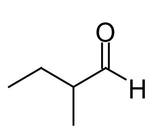
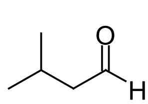
| FEMA | CAS | Principal Name | Molecular Weight | Calculated Vapor PressureValue | PEL Data[a,b] | Reported Poundage[c] (lbs) |
|---|---|---|---|---|---|---|
| 2742 | 554-12-1 | Methyl propionate  | 88.11 | 68.8 mm Hg 20 ºC<br>87.9 mm Hg 25 ºC | NA | 1995: 270<br>2005: 400<br>2010: 1,000 |
| 3647 | 556-82-1 | 3-Methyl-2-buten-1-ol  | 86.13 | 1.61 mm Hg 20 ºC<br>2.36 mm Hg 25 ºC | NA | 1995: 65<br>2005: 1<br>2010: 6 |
| 3407 | 497-03-0 | 2-Methyl-2-butenal  | 84.12 | 13.4 mm Hg 20 ºC<br>17.9 mm Hg 25 ºC | NA | 1995: 3<br>2005: 0.7<br>2010: 0.1 |
| 3646 | 107-86-8 | 3-Methyl-2-butenal  | 84.12 | 6.14 mm Hg 20 ºC<br>8.35 mm Hg 25 ºC | NA | 1995: 0<br>2005: 4<br>2010: 3 |
| 2731 | 108-10-1 | 4-Methyl-2-pentanone  | 100.16 | 16.6 mm Hg 20 ºC<br>21.8 mm Hg 25 ºC | OSHA PEL -TWA 100 ppm, 410 mg/m3 | 1995: 19<br>2005: 5<br>2010: 1 |
| 3368 | 141-79-7 | 4-Methyl-3-penten-2-one  | 98.15 | 7.9 mm Hg 20 ºC<br>12.3 mm Hg 25 ºC | OSHA PEL - TWA 25 ppm, 100 mg/m3 | 1995: 0<br>2005: 0<br>2010: 15 |
| 2691 | 96-17-3 | 2-Methylbutyraldehyde  | 86.13 | 6.9 mm Hg 20 ºC<br>10.4 mm Hg 25 ºC | NA | 1995: 33<br>2005: 87<br>2010: 38 |
| 2692 | 590-86-3 | 3-Methylbutyraldehyde  | 86.13 | 39.8 mm Hg 20 ºC<br>51.6 mm Hg 25 ºC | NA | 1995: 3,290<br>2005: 6,480<br>2010: 6,700 |

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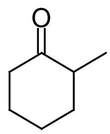
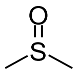
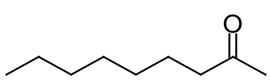
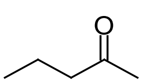
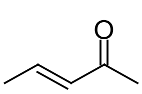
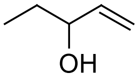
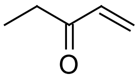
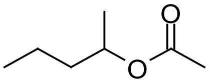
| *FEMA* | *CAS* | *Principal Name* | *Molecular Weight* | *Calculated Vapor PressureValue* | *PEL Data*[a,b] | *Reported Poundage*[c] *(lbs)* |
|---|---|---|---|---|---|---|
| 3946 | 583-60-8 | 2-Methylcyclohexanone<br> | 112.17 | 2.17 mm Hg 20 °C<br>3.01 mm Hg 25 °C | OSHA PEL - Skin TWA 100 ppm, 460 mg/m3 | 1995: NA<br>2005: 0<br>2010: 0 |
| 3875 | 67-68-5 | Methylsulfinylmethane<br> | 78.14 | 0.427 mm Hg 20 °C<br>0.622 mm Hg 25 °C | NA | 1995: NA<br>2005: 0.9<br>2010: 0.8 |
| 2785 | 821-55-6 | 2-Nonanone<br> | 142.24 | 0.449 mm Hg 20 °C<br>0.647 mm Hg 25 °C | NA | 1995: 3,520<br>2005: 1,000<br>2010: 3,500 |
| 2842 | 107-87-9 | 2-Pentanone<br> | 86.13 | 30.5 mm Hg 20 °C<br>39.4 mm Hg 25 °C | OSHA PEL - TWA 200 ppm, 700 mg/m3 | 1995: 640<br>2005: 1,140<br>2010: 1,900 |
| 3417 | 625-33-2 | 3-Penten-2-one<br> | 84.12 | 17.3 mm Hg 25 °C | NA | 1995: 0<br>2005: 0<br>2010: 0.1 |
| 3584 | 616-25-1 | 1-Penten-3-ol<br> | 86.13 | 6.47 mm Hg 20 °C<br>9.13 mm Hg 25 °C | NA | 1995: 20<br>2005: 160<br>2010: 150 |
| 3382 | 1629-58-9 | 1-Penten-3-one<br> | 84.12 | 29.5 mm Hg 20 °C<br>38.2 mm Hg 25 °C | NA | 1995: 2<br>2005: 340<br>2010: 600 |
| 4012 | 626-38-0 | 2-Pentyl acetate<br> | 130.19 | 7.22 mm Hg 20 °C<br>9.78 mm Hg 25 °C | OSHA PEL - TWA 125 ppm, 650 mg/m3 | 1995: NA<br>2005: 0<br>2010: 0 |

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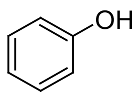
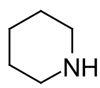
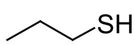
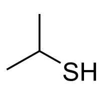
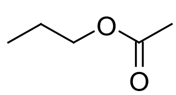
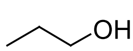
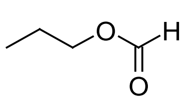
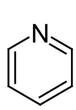
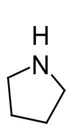
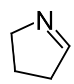
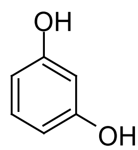
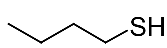
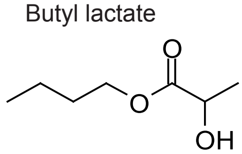
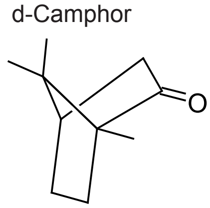
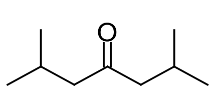
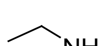
| FEMA | CAS | Principal Name | Molecular Weight | Calculated Vapor PressureValue | PEL Data[a,b] | Reported Poundage[c] (lbs) |
|---|---|---|---|---|---|---|
| 3223 | 108-95-2 | Phenol  | 94.11 | 0.193 mm Hg 20 ºC<br>0.323 mm Hg 25 ºC | OSHA PEL - Skin TWA 5 ppm, 19 mg/m3 | 1995: 9<br>2005: 12<br>2010: 2400 |
| 2908 | 110-89-4 | Piperidine  | 85.15 | 22 mm Hg 20º C<br>28.9 mm Hg 25 ºC | NA | 1995: 1,610<br>2005: 200<br>2010: 52 |
| 3521 | 107-03-9 | Propanethiol  | 76.16 | 114 mm Hg 20 ºC<br>144 mm Hg 25 ºC | NA | 1995: 120<br>2005: 12<br>2010: 5 |
| 3897 | 75-33-2 | 2-Propanethiol  | 76.16 | 265 mm Hg 25 ºC | NA | 1995: NA<br>2005: 0<br>2010: 0.1 |
| 2925 | 109-60-4 | Propyl acetate  | 102.13 | 26.8 mm Hg 20 ºC<br>35.1 mm Hg 25 ºC | OSHA PEL - TWA 200 ppm, 840 mg/m3 | 1995: 3,110<br>2005: 2,610<br>2010: 7,200 |
| 2928 | 71-23-8 | Propyl alcohol  | 60.1 | 16.9 mm Hg 20 ºC<br>23.2 mm Hg 25 ºC | OSHA PEL - TWA 200 ppm, 500 mg/m3 | 1995: 8,470<br>2005: 9,010<br>2010: 8,000 |
| 2943 | 110-74-7 | Propyl formate  | 88.11 | 64 mm Hg 20 ºC<br>84 mm Hg 25 ºC | NA | 1995: 110<br>2005: 890<br>2010: 1,400 |
| 2966 | 110-86-1 | Pyridine  | 79.10 | 14.5 mm Hg 20 ºC<br>19.3 mm Hg 25 ºC | OSHA PEL - TWA 5 ppm, 15 mg/m3 | 1995: 71<br>2005: 120<br>2010: 1,100 |
| 3523 | 123-75-1 | Pyrrolidine  | 71.12 | 49 mm Hg 20 ºC<br>66.5 mm Hg 25 ºC | NA | 1995: 28<br>2005: 12<br>2010: 9 |

**CONTINUED**

| FEMA | CAS | Principal Name | Molecular Weight | Calculated Vapor PressureValue | PEL Data[a,b] | Reported Poundage[c] (lbs) |
|---|---|---|---|---|---|---|
| 3898 | 5724-81-2 | 1-Pyrroline  | 69.1 | 80.7 mm Hg 25 ºC | NA | 1995: NA<br>2005: 0<br>2010: 0 |
| 3589 | 108-46-3 | Resorcinol  | 110.1 | 5.90 x 10-5 mm Hg 20 ºC<br>1.2 x 10-4 mm Hg 25 ºC | PEL-TWA 10 ppm; STEL 20 ppm (see Footnote d) | 1995: 5<br>2005: 0<br>2010: 0 |
| **Other Flavoring Substances with OSHA PEL's** | | | | | | |
| 3478 | 109-79-5 | 1-Butanethiol  | 90.19 | 39.9 mm Hg 25 ºC | OSHA PEL - TWA 10 ppm, 35 mg/m3 | 1995: 0.1<br>2005: 1<br>2010: 2 |
| 2205 | 138-22-7 | Butyl lactate  | 146.19 | 0.109 mm Hg 20 ºC<br>0.17 mm Hg 25 ºC | NIOSH REL-TWA 5 ppm | 1995: 410<br>2005: 1,060<br>2010: 2,000 |
| 2230 | 464-49-3 | d-Camphor  | 152.24 | 0.00604 mm Hg 20 ºC<br>0.0107 mm Hg 25 ºC | OSHA PEL - TWA 2 mg/m3 | 1995: 6,630<br>2005: 140<br>2010: 160 |
| 3537 | 108-83-8 | 2,6-Dimethyl-4-heptanone  | 142.24 | 1.54 mm Hg 20 ºC<br>2.15 mm Hg 25 ºC | OSHA PEL - TWA 50 ppm, 290 mg/m3 | 1995: 0<br>2005: 0<br>2010: 0 |
| 4236 | 75-04-7 | Ethylamine  | 45.09 | 153 mm Hg 25 ºC | OSHA PEL - TWA 10 ppm, 18 mg/m3 | 1995: NA<br>2005: 0<br>2010: 0 |

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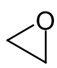
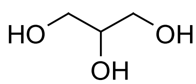
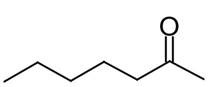
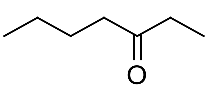
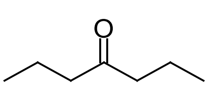
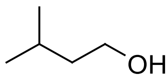
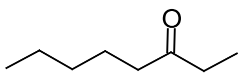
| FEMA | CAS | Principal Name | Molecular Weight | Calculated Vapor PressureValue | PEL Data[a,b] | Reported Poundage[c] (lbs) |
|---|---|---|---|---|---|---|
| 2433 | 75-21-8 | Ethylene oxide  | 44.05 | 1250 mm Hg 25 ºC | OSHA PEL- TWA 1ppm, OSHA STEL 5 ppm/15 min | 1995: 0<br>2005: 0<br>2010: 0 |
| 2525 | 56-81-5 | Glycerol  | 92.10 | 7.98 x 10-5 mm Hg 25 ºC | OSHA PEL - Glycerol mist - TWA 15 mg/m3 (total dust); 5 mg/m3 (respirable fraction) | 1995: 3,620,000<br>2005: 2,030,000<br>2010: 1,640,000 |
| 2544 | 110-43-0 | 2-Heptanone  | 114.19 | 3.59 mm Hg 20 ºC<br>4.91 mm Hg 25 ºC | OSHA PEL - TWA 100ppm, 465 mg/m3 | 1995: 2,280<br>2005: 3,100<br>2010: 3,600 |
| 2545 | 106-35-4 | 3-Heptanone  | 114.19 | 4.31 mm Hg 20 ºC<br>5.86 mm Hg 25 ºC | OSHA PEL - TWA 50ppm, 230 mg/m3 | 1995: 120<br>2005: 100<br>2010: 170 |
| 2546 | 123-19-3 | 4-Heptanone  | 114.19 | 4.93 mm Hg 20 ºC<br>6.69 mm Hg 25 ºC | REL-TWA 50 ppm | 1995: 130<br>2005: 57<br>2010: 37 |
| 2057 | 123-51-3 | Isoamyl alcohol  | 88.15 | 2.66 mm Hg 20 ºC<br>3.84 mm Hg 25 ºC | OSHA PEL - TWA 100 ppm, 360 mg/m3 (for primary and secondary) | 1995: 36,600<br>2005: 29,900<br>2010: 42,000 |
| 2803 | 106-68-3 | 3-Octanone  | 128.22 | 1.68 mm Hg 20 ºC<br>2.34 mm Hg 25 ºC | OSHA PEL - TWA 25 ppm, 130 mg/m3. OSHA lists standard for this material under CAS Number 541-85-5 (Federal Register 7/5/89). | 1995: 12<br>2005: 75<br>2010: 11 |

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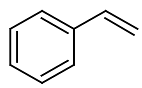
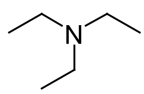
| FEMA | CAS | Principal Name | Molecular Weight | Calculated Vapor PressureValue | PEL Data[a,b] | Reported Poundage[c] (lbs) |
|---|---|---|---|---|---|---|
| 3233 | 100-42-5 | Styrene  | 104.15 | 3.67 mm Hg 20 ºC<br>5.05 mm Hg 25 ºC | OSHA PEL - TWA 100 ppm; Acceptable ceiling concentration - 200 ppm; Acceptable maximum peak above the acceptable ceiling concentration for an 8-hr shift is 600 ppm for 5 minutes in any 2 hours | 1995: 9<br>2005: 2<br>2010: 0.6 |
| 4246 | 121-44-8 | Triethylamine  | 101.19 | 59.1 mm Hg 25 ºC | OSHA PEL - TWA 25ppm, 100mg/m3 | 1995: NA<br>2005: 9<br>2010: 0 |

[a] Additional occupational exposure guidance may be available from the American Conference of Governmental Industrial Hygienists (ACGIH®).

[b] PEL=OSHA Permissible Exposure Limit; REL=NIOSH Recommended Exposure Limit; STEL=Short Term Exposure Limit;TWA=8 hour Time Weighted Average Exposure

[c] NA=Not available

[d] PEL for resorcinol subsequently rescinded and is currently not in force.

# List of Acronyms

| | |
|---|---|
| ACGIH | American Conference of Government Industrial Hygienists |
| AIHA | American Industrial Hygiene Association |
| Cal/OSHA | California Division of Occupational Safety and Health |
| CAS | Chemical Abstract Service |
| FDA | Food and Drug Administration |
| FEMA | Flavor and Extract Manufacturers Association |
| FFIDS | Flavor and Fragrance Ingredient Data Sheet |
| FISHEP | Flavor Industry Safety and Health Evaluation Program |
| GHS | Globally Harmonized System of Classification and Labeling of Chemicals |
| HCS | OSHA Hazard Communication Standard |
| HHE | NIOSH Health Hazard Evaluation |
| IFRA | International Fragrance Association |
| IOFI | International Organization of the Flavor Industry |
| MSDS | Material Safety Data Sheet |
| NEP | OSHA National Emphasis Program |
| NJH | National Jewish Health |
| NIOSH | National Institute of Occupational Safety and Health |
| OEL | Occupational Exposure Limit |
| OSHA | Occupational Safety and Health Administration |
| PEL | Permissible Exposure Limit |
| REL | Recommended Exposure Limit |
| STEL | Short-Term Exposure Limit |
| TERA | Toxicology Excellence for Risk Assessment |
| TLV | Threshold Limit Value |
| TWA | Time-Weighted Average |

Maintaining safe and healthy workplaces is a matter of utmost importance to FEMA and its members. FEMA consulted with experts on the development of this document and made extensive use of a wide variety of information resources. As described in detail in their report, the application of this information to your workplace is a function of specific aspects of your workplace and the products manufactured and handled. Because of the unique nature of each workplace, the information in this report should be considered only a general guide. FEMA is not responsible for either the use or nonuse of the information, or any actions, or failure to act, in any specific workplace based on reliance on the report. It is your individual responsibility to verify this information as it applies to your workplace before acting, and to comply with all relevant federal, state, and local laws and ordinances. We strongly urge you to consult with appropriate experts regarding the circumstances relevant to respiratory health and safety in your facilities.

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