Evaluation of a Garlic Paste Production Process

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Contents

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

Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from a facility that processes custom food orders. The employer was concerned about employees' eye and respiratory symptoms during garlic processing.

What We Did

- We visited the facility in March and May 2012.
- We observed employees' work practices and the local exhaust ventilation system above the kettles.
- We reviewed the written respiratory protection program.
- We took air samples to look for volatile organic compounds and diallyl disulfide, a component of garlic vapor.

What We Found

- Employees were required to wear respiratory protection while processing garlic.
- Local exhaust ventilation did not effectively capture garlic vapors from large kettles.
- The ventilation system did not keep garlic odors within the kettle room.
- We found diallyl disulfide in the air.
- The company provided more outdoor air to the kettle room after our visit to dilute odors. Employees still reported having eye and respiratory irritation.

We visited the food processing facility because employees had eye and respiratory irritation while processing garlic. We found that the local exhaust ventilation system did not control garlic vapors and cooking odors. We recommend improving the local exhaust ventilation in the kettle room, adding local exhaust ventilation in the chopping areas, and changing work practices to control odors during garlic processing.

What the Employer Can Do

- Contact a qualified ventilation engineer about improving local exhaust ventilation in the kettle room.
- Keep the kettle room under negative pressure when processing garlic to help contain the odors.
- Limit employee access to the kettle room during garlic processing to only those who need to work in that area.
- Keep the kettles closed as much as possible, and store and carry garlic in closed bins to minimize garlic vapor release.
- Create a fixed schedule for changing out organic vapor cartridges in respirators. Do not wait until employees smell odors to replace cartridges.

- Develop standard operating procedures that limit handling garlic or garlic-containing equipment.
- Ask employees to report any symptoms they consider to be work related to their supervisor and personal physician.

What Employees Can Do

- Use required personal protective equipment during garlic processing.
- Report any symptoms you believe to be work related to your supervisor and personal physician.

Abbreviations

ACGIH®	American Conference of Industrial Hygienists
CAS	Chemical Abstract Service
CFR	Code of Federal Regulations
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
ppm	Parts per million
TWA	Time-weighted average
TLV®	Threshold limit value
VOC	Volatile organic compounds
WEEL™	Workplace environmental exposure level

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Introduction

The Health Hazard Evaluation Program received a request for a health hazard evaluation from managers at a food processing company. Employees had reported eye irritation, burning eyes, blurred vision, and burning and sore throat during garlic processing. We visited the facility in March and May 2012. After each visit, we sent letters to the company and an employee representative summarizing our activities.

Garlic cooking and processing occurred twice monthly. At the time of this evaluation, employees were working 10-hour shifts from 6:00 a.m. to 4:00 p.m. Five employees spent at least part of their shift processing or packing garlic. Employees mechanically chopped approximately 4,000 pounds of garlic per batch. The garlic was then added to a cooking oil at a specific temperature for 18–25 minutes in either of two 400-gallon kettles. Processing time from chopping garlic to pumping garlic paste from the kettle into buckets was approximately 2–3 hours. Employees produced four kettles of garlic paste per day. Only employees who were processing garlic worked in this room when the operation was occurring. While the garlic cooked, some employees left to work in other locations in the facility, while others remained to prepare for the next step.

Methods

The objectives of this evaluation were to determine (1) which volatile organic compounds (VOCs) were being released and (2) what actions could be taken to minimize irritation and potentially eliminate the need for respiratory protection during garlic cooking and processing.

We visited the facility twice. During the first site visit we observed production processes, work practices, workplace conditions, and personal protective equipment use. We also spoke informally with employees about health concerns. We used thermal desorption tubes and Sulfinert® tubes to collect personal air samples for volatile organic compounds, including sulfur compounds, on three employees during garlic cooking and pumping processes. The thermal desorption tubes and Sulfinert® tubes were analyzed via gas chromatography and mass spectroscopy using National Institute for Occupational Safety and Health (NIOSH) Method 2549 [NIOSH 2015]. We did screening sampling during the first site visit to identify which VOCs were released and should be sampled for during our follow-up site visit. Additional details about air sampling and analysis are included in Appendix A.

After identifying diallyl disulfide (Chemical Abstract Service [CAS] 2179-57-9), an organic sulfur compound and a decomposition product of allicin (major organosulfur compound released from crushed or chopped garlic), in the screening samples, we collected personal air samples on five employees during garlic paste production on a second visit. For each employee we collected a series of personal air samples over their work shift using Chromosorb® 106 sorbent tubes during the garlic cooking process. We analyzed the tubes quantitatively for diallyl disulfide according to Occupational Safety and Health Administration (OSHA) Method PV2086 [OSHA 2015].

A NIOSH chemical and industrial engineer observed the processes and local exhaust ventilation emission capturing system (canopy hood). Later, we reviewed the company's respiratory protection program and a summary of the ventilation changes made after the second site visit.

Results

During our first site visit, we found that diallyl disulfide was a major constituent in the area air samples we collected when employees were making garlic paste. The other major compounds detected in the area air samples were allyl alcohol, methyl allyl sulfide, methyl allyl disulfide, methyl allyl trisulfide, and ethyl acetate. Major compounds found in each sample are shown in Table 1. Similar compounds were identified on the paired Sulfinert and thermal desorption tubes.

Table 1. PBZ air sampling for volatile organic compounds on March 19, 2012

Activity	Sample tube type	Sample time (military)	Major peaks
Pumping garlic into pails	Sulfinert	1003–1046	Allyl alcohol Ethyl acetate Methyl allyl disulfide Diallyl disulfide
	Thermal desorption	1042–1121	Allyl alcohol Octane Diallyl disulfide
Weighing garlic pails	Sulfinert	1000–1124	Allyl alcohol Octane Methyl allyl disulfide Diallyl disulfide Methyl allyl trisulfide
	Thermal desorption	1000–1124	Allyl alcohol Octane Methyl allyl disulfide Diallyl disulfide Methyl allyl trisulfide
Cooking process	Sulfinert	1415–1515	Ethyl acetate Dihydrofuran Methyl allyl sulfide Methyl allyl disulfide Limonene Diallyl disulfide
	Thermal desorption	1415–1515	Ethyl acetate Dihydrofuran Methyl allyl sulfide Methyl allyl disulfide Diallyl disulfide

Diallyl disulfide does not have occupational exposure limits (OELs). However, OELs have been established for a structurally similar compound, allyl propyl disulfide (CAS 2179-59-1), which is produced during onion processing (Appendix B). Like diallyl disulfide, allyl propyl disulfide is a decomposition product of allicin. On the basis of irritating effects reported in a 1946 study in an onion drying facility, OSHA and NIOSH established OELs for allyl propyl disulfide of 2 parts per million (ppm). The American Conference of Governmental Industrial Hygienists (ACGIH) set a time-weighted average (TWA) threshold limit value (TLV) for allyl propyl disulfide at 0.5 ppm on the basis of irritation and lacrimation (causes tear formation in the eyes) and as a sensitizer, which means it can cause allergy. NIOSH also has a short-term exposure limit (15 minutes) of 3 ppm for allyl propyl disulfide. More information about occupational exposure limits is in Appendix B.

At 7:00 a.m. on the day of our site visit the temperature was 75°F, and relative humidity was 75% in the facility; at this time the employees were chopping garlic and heating oil in the kettles. All but one employee spent most of their shifts in the garlic processing area. At the beginning of the shift, employee D heated oil in the kettles and loaded most of the garlic into the kettles for the first batch after the garlic had been cut by employees A, B, and C. For the remainder of the shift, employee D was in and out of the area taking temperatures of cooking and cooked garlic and shrink wrapping the final product. Employee B loaded cut garlic into the kettle at the beginning of the shift for the first batch of cooked garlic and around hour 3 for the second batch; then employee B pumped cooked garlic into the finished pails. Employee C cut garlic for the first batch of cooked garlic then lidded and sealed the final product and opened boxes for the rest of the shift starting around hour 2. Employee E started working in the garlic production area around hour 3 of the shift by labeling finished pails of cooked garlic. After working elsewhere in the plant employee E returned to the garlic processing area to seal filled pails of cooked garlic. Employee A cut garlic for most of the shift and scooped and weighed garlic.

Diallyl disulfide concentrations varied over the work shift (Table 2). The highest task-based concentrations of diallyl disulfide occurred when three employees were working in the kettle room doing the following tasks: cutting garlic, weighing garlic pails, and labelling and placing pails on pallets. Within some of the tasks we found a substantial range of exposures. For example, the range of concentrations during “cutting garlic” was 0.09–0.63 ppm and the range during “loading kettles” was 0.06–0.47 ppm.

Table 2. Task-based personal air sampling for diallyl disulfide on May 21, 2012

ID	Batch #	Task	Sample time (military)	Total time (minutes)	Concentration (ppm)
A	1	Cutting garlic	0622–0842	137	0.63
	1	Weighing garlic pails	0842–1046	125	0.37
	2	Cutting garlic	1116–1250	94	0.09
	2	Weighing garlic pails	1337–1503	86	0.57
B	1	Unloading garlic	0631–0842	130	0.24
	1	Pumping garlic into pails	0843–1047	123	0.20
	2	Loading kettles	1125–1250	88	0.06
	2	Pumping garlic into pails	1337–1504	87	0.43
C	1	Unloading garlic	0616–0840	145	0.30
	1	Placing lid on pail	0841–1046	126	0.34
	2	Unloading garlic	1116–1250	94	0.09
	2	Placing lid on pail	1337–1502	85	0.47
D	1	Loading kettles	0635–0847	130	0.47
	1	Miscellaneous activities	0848–1048	119	0.48
	2	Miscellaneous activities	1337–1506	84	0.18
E*	1	Labeling/placing pails on pallets	0909–1047	96	0.52
	2	Labeling/placing pails on pallets	1337–1502	84	0.51

*Employee E only participated in personal sampling during garlic processing activities, but not for the full shift.

Measured full-shift exposures were 0.47 ppm for the employee loading kettles and doing miscellaneous activities and 0.43 ppm for the employee cutting garlic and weighing garlic pails (Table 3). Full-shift exposures for the other two employees we monitored for their full shift were 0.26 and 0.30 ppm. We did not measure the full-shift exposure of Employee E.

Table 3. Full shift personal air sampling for diallyl disulfide on May 21, 2012

ID	Activity	Total time (minutes)	Concentration (ppm)
A	Cutting garlic, weighing garlic pails	390	0.43
B	Unloading garlic, loading kettles, pumping garlic into pails	476	0.26
C	Unloading garlic, placing lid on pail	498	0.30
D*	Loading kettles, miscellaneous	343	0.47

*Employee D left the site for several hours but returned before the end of his shift. The full-shift sampling concentration only includes the time spent at the site.

Observations and Ventilation Evaluation

The company used two pedestal floor fans in the kettle room to increase air circulation. One fan directed air into the kettle room, and the other directed air out of the kettle room. Four kettles were located along the south exterior wall of the kettle room and a canopy hood used for local exhaust ventilation was mounted on the wall and positioned about 5 feet above the kettles. However, the local exhaust ventilation over the kettles did not effectively capture steam and garlic vapor. Additionally, some of the exhaust ventilation did not work. Previously, these larger kettles had been used to cook soup, and the existing local exhaust ventilation system had not been modified to capture vapors created by garlic paste production. Several aspects of the ventilation system design may have contributed to the ineffectiveness: (1) the diameter of the two larger kettles used for garlic processing exceeded the width of the overhead exhaust hood and (2) the exhaust rate or capture velocity was not sufficient to contain vapors produced during garlic cooking. As a result, garlic odors entered other areas of the facility during garlic processing. Additionally, during informal conversations, employees reported the odor and irritation were worst when cooking garlic in the kettles.

In the chopping area, three employees chopped frozen garlic cloves using a machine and put the chopped garlic in large buckets. Some employees wore Flavorseal™ food grade, lightly powdered, synthetic gloves (CMS C-GSPXL) when cutting garlic and when they put garlic in pails. Employees also wore safety glasses and steel toe boots. Concurrently, two other employees organized the cooking oil containers, heated the oil in the kettles, and loaded the chopped garlic into the kettles. The containers of chopped garlic were not covered during transport. As required by the company during garlic processing, one employee who chopped garlic and lidded the final garlic product wore a 3M™ Ultimate FX full facepiece air-purifying respirator with an organic vapor cartridge. The remaining four employees manufacturing garlic paste wore 3M Breathe Easy™ loose-fitting powered air-purifying respirators with organic vapor cartridges.

At the time of the site visit in March 2012, the company was beginning to implement a respiratory protection program, but did not have a written program. The company completed the written program shortly after our site visit and provided a copy to us. The written program contained the basic elements required by the OSHA respiratory protection standard, including respirator selection, medical evaluation, respirator training, fit testing, respirator use, and handling of disposable respirators [29 CFR 1910.134]. The written respiratory protection program called for changing the organic vapor cartridges when employees could smell garlic when using the respirator. This is not an allowable practice under the OSHA respiratory protection standard. OSHA requires companies to develop a cartridge change-out schedule on the basis of airborne concentrations and respirator use conditions.

We contacted the company in September 2014 to ask about their current concerns and what changes, if any, they had made in their respiratory protection program and kettle ventilation system. The company reported that they had not changed the respiratory protection program. The company continued to require all employees working on this process to wear loose-fitting powered air-purifying respirators or full facepiece air-purifying respirators with organic vapor cartridges. The company had consulted a ventilation engineer and changed the ventilation systems in the kettle room. The ventilation change was intended to provide up to 11,000 cubic feet per minute of outdoor air for dilution ventilation. However, according to the company, these ventilation changes did not reduce garlic vapors to nonirritating levels. Dilution ventilation can be useful when there are many diffuse emission sources across a wide area; however, it is not likely to be effective for controlling point-source generated emissions. In this plant, the strongest garlic vapors originated primarily from two large stationary kettles; therefore, a well-designed local exhaust ventilation system, paired with the new higher capacity general ventilation system, would be the most efficient means to control garlic vapor emissions.

Discussion

Onion and garlic vapors are known to irritate the eyes, nose, mouth, and other mucus membranes [Block 2010]. Onion and garlic vapors contain complex mixtures of VOCs that are released when these vegetables are chopped, crushed, or damaged. These VOCs are produced through a series of chemical and enzymatic reactions, causing the typical garlic odor [Block 2010]. Organic sulfur compounds, including diallyl disulfide, are the primary constituents of garlic odors [Edris and Fadel 2002; Block 2010]. Unlike onion vapor, garlic vapors do not contain lachrymatory factor, propanethial S-oxide, which stimulates tear production in the eye [Block 2010].

Researchers have found that inhaled garlic dust can cause allergic asthma and inflammation of the mucous membranes inside the nose in cooks and garlic workers [Falleroni et al. 1981; Lybarger et al. 1982; Añibarro et al. 1997; Jappe et al. 1999; Pires et al. 2002; Bassioukas et al. 2004; Hubbard and Goldsmith 2005]. Some people who are allergic or sensitive to garlic have had reactions to diallyl disulfide, allyl propyl disulfide, 2-propenethiol, and allicin compounds that are present in crushed garlic [Papageorgiou et al. 1983; Hubbard and Goldsmith 2005].

Individuals who handle garlic can develop both allergic and irritant dermatitis or rash. Extracts from crushed garlic, diallyl disulfide in particular, can cause sensitization and contact dermatitis among those already sensitized [Papageorgiou et al. 1983]. At the time of our visits, employees wore gloves to protect their skin from dermal contact with the garlic. In our review of the scientific literature, we found one study that evaluated the efficacy of different gloves. The researchers found that commonly used disposable gloves (latex, nitrile, vinyl, and polyethylene) and reusable thicker gloves (cotton-lined rubber, vinyl dishwashing, neoprene-coated rubber glove, and "pearl-lined finish" rubber glove) did not prevent a skin reaction in one sensitized individual when exposed to 1% diallyl disulfide [Moyle et al. 2004].

Diallyl disulfide concentrations represent a large fraction but not all of the irritating sulfurous compounds. Even if diallyl disulfide concentrations were kept below 0.5 ppm, employees may continue to experience irritation of the eyes and mucous membranes due to cumulative exposure to all components of garlic oils, including other sulfides, if respiratory protection is not used. Additionally, some employees may be more sensitive to components of garlic vapors and experience irritation at concentrations lower than the OELs.

Conclusions

We found diallyl disulfide, a chemical in garlic vapor, in personal air samples when employees were making garlic paste. Although we do not know if this chemical alone is responsible for the eye and respiratory irritation reported by employees who processed the garlic, diallyl disulfide is a main component of garlic oil and is considered a mucous membrane and skin irritant and skin allergen. We also identified other VOCs in the screening samples, some of which can also cause irritation and allergy. The local exhaust ventilation system above the cooking kettles did not control garlic vapors and there was no local exhaust ventilation in the cutting area. Gloves used to handle garlic at the site may not protect against allergic reaction in individuals who are already sensitized to garlic.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage the food production company to use a labor-management health and safety committee or working group to discuss our recommendations and develop an action plan. Those involved in the work can best set priorities and assess the feasibility of our recommendations for the specific situation at the food production company.

Our recommendations are based on an approach known as the hierarchy of controls (Appendix B). This approach groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or feasible, administrative measures and personal protective equipment may be needed.

Engineering Controls

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

1. Redesign the local exhaust ventilation system above the kettles used to process garlic paste to make it more efficient in containing and exhausting the garlic vapors. This could include increasing the width of the exhaust hoods so that the hoods are wider than the kettles, positioning the hoods closer to the kettles, installing flexible strip curtains around the kettles, and increasing the local exhaust ventilation rate to offset the increased outdoor air provided to the kettle room. Consult with a ventilation engineer familiar with commercial food production to help improve exhaust ventilation.
2. Install local exhaust ventilation in the garlic cutting area.
3. Maintain the kettle room used to process garlic paste under slight negative pressure (less than 0.02″ water gauge) relative to the surrounding areas. This means that room air should flow from surrounding areas into the kettle room to reduce the migration of cooking odors from garlic processing. However, the building overall should be positively

pressured compared to the outdoors to prevent contamination during food processing. Evaluate the pressure differential after any ventilation system modification.

4. Reduce or eliminate manual handling of garlic or garlic-contaminated equipment by providing tools to perform garlic transferring tasks or develop standard operating procedures that eliminate dermal contact with garlic (pouring garlic vs. scooping). Discourage manual handling of garlic or garlic-processing equipment.

Administrative Controls

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

1. Minimize garlic vapor emissions by keeping the kettles closed when possible and storing and transporting cut garlic in closed bins.
2. Limit employee access to the kettle room during garlic processing to only those who need to work in that area.
3. Establish a respirator cartridge change out schedule to replace organic vapor cartridges at fixed intervals. Do not rely on odor breakthrough to determine when a new cartridge should be installed. Consult OSHA Respiratory eTools guidance on cartridge change out scheduling at https://www.osha.gov/SLTC/etools/respiratory/change_schedule.html and NIOSH guidance on where to find trusted information about cartridge change out scheduling at http://www.cdc.gov/niosh/npptl/topics/respirators/disp_part/RespSource3end.html#howcalculate.
4. Instruct employees to report any symptoms they consider to be work related to their supervisor and personal physician.
5. Evaluate the effectiveness of local exhaust ventilation changes using exposure monitoring and employee symptom reports to determine if respiratory protection can be eliminated or reduced.

Personal Protective Equipment

Personal protective equipment is the least effective means for controlling hazardous exposures. Proper use of personal protective equipment requires a comprehensive program and a high level of employee involvement and commitment. The right personal protective equipment must be chosen for each hazard. Supporting programs such as training, change-out schedules, and medical assessment may be needed. Personal protective equipment should not be the sole method for controlling hazardous exposures. Rather, personal protective equipment should be used until effective engineering and administrative controls are in place.

1. Require employees to wear gloves if handling garlic or equipment that was used to process garlic is unavoidable. Consider using heavy gloves and limiting manual handling of garlic to reduce dermal exposure.

2. Contact glove manufacturers to help find the appropriate glove materials to protect employees handling garlic.

Appendix A: Methods

Volatile Organic Compound Sampling and Analysis

We collected personal air samples for VOCs using thermal desorption tubes and Sulfinert tubes attached to SKC model air sampling pumps calibrated at 100 cubic centimeters per minute. The thermal desorption tubes contained three beds of sorbent material: (1) 90 milligrams of Carbopack™ Y, (2) 115 milligrams of Carbopack B, and (3) 150 milligrams Carboxen™. They were heated for 2 hours at 350°C. The Sulfinert tubes contained two beds of sorbent, 200 milligrams of Tenax TA and 200 milligrams of Spherocarb. They were heating for 1 hour at 330°C. After sampling, the sampling tubes were stored in a cooler and then qualitatively analyzed for VOCs according to NIOSH Method 2549 [NIOSH 2015]. For the Sulfinert tubes the helium purge flow rate was reduced and the flow path temperature was lowered to maintain the integrity of labile compounds.

Diallyl Disulfide Sampling

We collected personal air samples for diallyl disulfide using Chromosorb® 106 tubes attached to SKC pocket pumps calibrated at 1 liter per minute. After sampling, the sorbent tubes were stored in a cooler and then quantitatively analyzed for diallyl disulfide according to OSHA Method PV2086 [OSHA 2015]. Samples were desorbed with trichloroethylene and analyzed by gas chromatography using a flame photometric detector.

Appendix B: Occupational Exposure Limits

NIOSH investigators refer to mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents when evaluating workplace hazards. OSHA, ACGIH, and NIOSH have not developed an OEL for diallyl disulfide, but have established OELs for allyl propyl disulfide, a structurally related chemical with similar health effects. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a pre-existing medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a TWA exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended short-term exposure limits or ceiling values. Unless otherwise noted, the short-term exposure limit is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- The U.S. Department of Labor OSHA permissible exposure limits (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits. These limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH recommended exposure limits are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. Recommended exposure limits are published in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2010]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Other OELs commonly used and cited in the United States include the TLVs, which are recommended by the American Conference of Governmental Industrial Hygienists, a professional organization, and the workplace environmental exposure levels (WEELs), which are recommended by the American Industrial Hygiene Association, another professional organization. The TLVs and WEELs are developed by committee members of these associations from a review of the published, peer-reviewed literature. These OELs are not consensus standards. TLVs are considered voluntary exposure guidelines

for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2015]. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2015].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at http://www.dguv.de/ifa/GESTIS/GESTIS-Internationale-Grenzwerte-für-chemische-Substanzen-limit-values-for-chemical-agents/index-2.jsp, contains international limits for more than 1,500 hazardous substances and is updated periodically.

OSHA requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970 (Public Law 91–596, sec. 5(a)(1))]. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions. NIOSH investigators also encourage use of the hierarchy of controls approach to eliminate or minimize workplace hazards. This includes, in order of preference, the use of (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting employee health. Control banding focuses on how broad categories of risk should be managed. Information on control banding is available at http://www.cdc.gov/niosh/topics/ctrlbanding/. This approach can be applied in situations where OELs have not been established or can be used to supplement existing OELs.

Allyl Propyl Disulfide

OSHA and NIOSH have established full shift OELs of 2 ppm for allyl propyl disulfide, which is chemically similar to diallyl disulfide, and is also a component of garlic odors. NIOSH also has a short-term exposure limit of 3 ppm for allyl propyl disulfide. ACGIH and the German Research Foundation (Deutsche Forschungsgemeinschaft) have an OEL for allyl propyl disulfide of 0.5 ppm. All of these limits were based on irritating properties of this chemical on the mucous membranes [Feiner et al. 1946]. Research on the effects of long-term exposure is very limited. No human, animal model, or epidemiological studies have been conducted on the chronic effects or carcinogenicity of allyl propyl disulfide. In one study, allyl propyl disulfide was found to be non-genotoxic using a bacterial model [Zeiger et al. 1988]. ACGIH considers allyl propyl disulfide to cause dermal sensitization on the basis of an animal model study where diallyl disulfide caused contact dermatitis and human reports of dermatitis following skin contact with garlic [Feiner et al. 1946; Papageorgiou et al. 1983]. On the basis of structural similarities, diallyl disulfide may be expected to elicit similar health effects as allyl propyl disulfide.

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Availability of Report

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